PB-231 676

35MM AERIAL PHOTOGRAPHY FOR MEASUREMENT ANALYSIS PRESENTATION

Public Health Service
Washington, D. C.

1963

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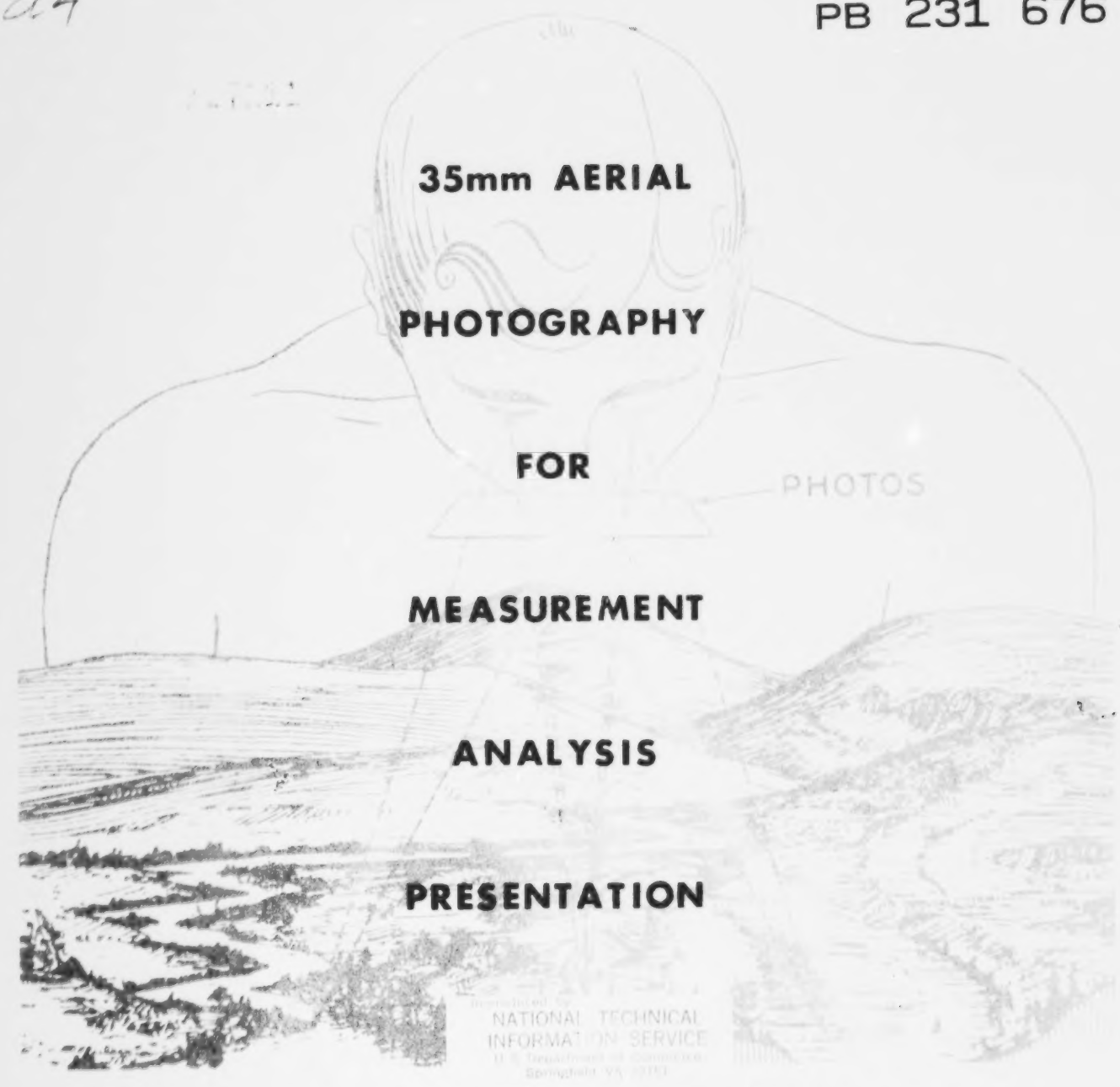
35mm AERIAL PHOTOGRAPHY FOR MEASUREMENT ANALYSIS PRESENTATION



NATIONAL TECHNICAL INFORMATION SERVICE

PREPARED AND DISTRIBUTED

UNDER

U. S. PUBLIC HEALTH SERVICE

DIVISION OF WATER SUPPLY AND POLLUTION CONTROL

DEMONSTRATION GRANT WPD 20-01-1963

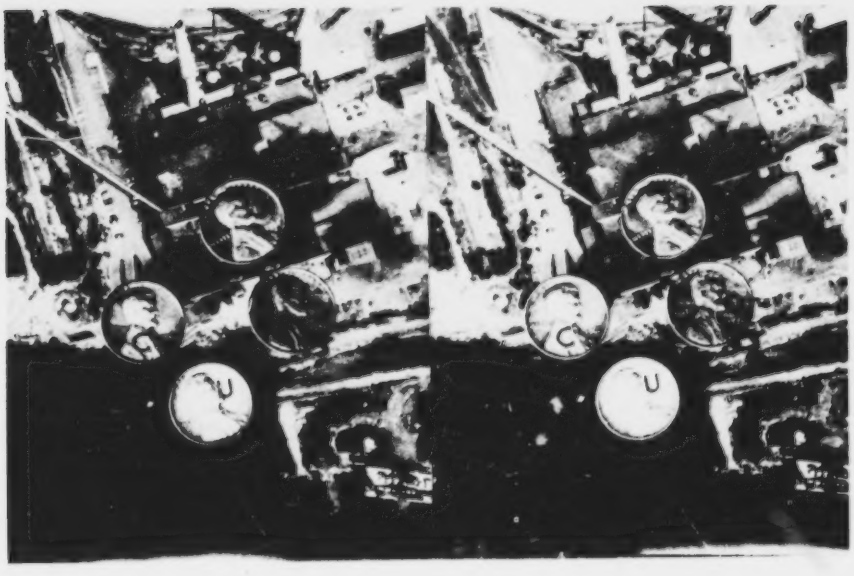
The cover overprint illustrates the "Giant Eyebase" concept. By simultaneous viewing of two overlapping, correctly positioned aerial photographs, viewed through a stereoscope, aerial photographic interpreter's "see" the terrain just as would the "Giant" in the overprint.

Can you see stereo?

Try the test on the back of this page.

The "Giant Eyebase" illustration is reprinted with the permission of Mr. Gomer T. McNeil, President, Photogrammetry, Inc., Rockville, Maryland.

PENNIES FROM HEAVEN



"Pennies from Heaven" is an old saying describing receipt of unexpected wealth. Aerial Photographic Interpretation and Aerial Photogrammetry save users an average of 80% in time and 40% in cost for most types of geographic analyses.

This "Stereogram"* illustrates how you gain these "Pennies from Heaven" -- from above, taking advantage of the best possible observation point, with an extremely precise type of camera. Even very small features are pictured, and in a way which permits the user to study the ground as though it were a precisely accurate, minutely detailed model.

This illustration is more than all this, however. It is a unique test of your ability to see stereo.

Using a folding stereoscope, as outlined in the Instruction Sheet "How to Use Folding Stereoscopes," study the illustration in stereo. If you are one of the 95 out of every 100 persons who <u>can</u> see stereo, the letters and numbers on the pennies will tell you a message -- reading from the coin which appears lowest up, in order.

Get the message? (Read the bottom of this page upside down.)

*Stereograms consist of sections of overlapping photographs positioned so that the pictured imagery can be seen in three dimensions.

(The message is "U C 3 D" -- You See 3-D. You are capable of seeing stereo.)

FORWARD

This Handbook has been compiled to fill a clear and present need as evidenced by comments received from Water Supply and Pollution Control groups throughout the United States.

In the course of several years research to develop faster, more efficient and more economical methods for collecting vital information about our National Water Resources through interpretation of aerial photography, a frequent complaint from State and Federal agencies has been that the aerial photography available from Government sources is several years old, or was taken at the "wrong" time of the year. The time factor, which may be so critical in water pollution work, where human lives are at stake, has crippled its extensive use.

The purpose of this Booklet is to outline simple techniques for taking photographs from aircraft with 35mm cameras, to overcome the reported time-factor handicaps.

It is hoped that this additional knowledge will aid planning groups, water supply and pollution control groups, conservation agencies, and others who need to gather and transmit information concerning our national water resources. The techniques described are fast, inexpensive and designed to augment conventional methods.

In addition to presenting techniques for taking pictures from aircraft, techniques are described for measuring area, distance and direction from the photographs, conducting limited types of aerial photographic interpretation and preparing aerial photographic illustrations for reports and oral presentations.

It is assumed that users of this booklet will know how to use 35mm cameras on the ground, and that they understand the basic terminology used in discussing photography and camera usage.

The user who knows and understands how to use a camera effectively on the ground should have little difficulty mastering the use of a camera in the air, following the directions outlined in this Handbook.

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ACKNOWLEDGMENTS

I am deeply indebted to Dr. Robert N. Colwell, University of California, Dr. Jack Van Lopik, Texas Instruments Corporation, Dallas, Texas, and Professor Charles E. Olson, Jr., University of Illinois, for their assistance in editing this Handbook.

Invaluable assistance was also given by the Eastman Kodak Company, Rochester, New York, Cessna Aircraft Company, Wichita, Kansas, and by Mr. C. B. Diamond, Diamond Aviation Sales, Inc., the Cessna Distributor in the Washington, D.C. area.

To Mr. Raymond M. Nelson I am particularly grateful for his assistance in preparation of Perspective Grids, as well as for some of my early education in the field of photogrammetry at the U.S. Naval Photographic Interpretation Center, where I received some of my early training while serving as an Officer in the U.S. Marine Corps.

This Handbook was prepared under Demonstration Grant WPD 20-01-1963, awarded to me as an individual by the Division of Water Supply and Pollution Control, U.S. Public Health Service, which organization has given me the encouragement and the funds to continue my efforts to hopefully, develop aerial methods for better, faster and more economical water supply and pollution control reconnaissance to augment ground methods.

Carl H. Strandberg

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I.

INTRODUCTION

Any photography taken from an aircraft can be called "aerial photography."

Aerial photography may be classified on the basis of the direction in which the camera was pointed when the picture was taken. It may also be classified according to scale, or in terms of the wavelengths of the reflected light which formed the image.

The first method of classification is sometimes called "geometric classification." If the camera lens was pointed toward the center of the earth when the pictures were taken, the aerial photographs are "vertical" photographs. The basic geometry of vertical aerial photography is shown in FIGURE 1. If the camera lens was pointed at any angle other than straight down, the photographs are classified as "oblique." "High Oblique" photographs are those in which the horizon can be seen. "Low Oblique" photographs are those which are taken with the camera pointed more nearly vertical, so that the horizon is not pictured.

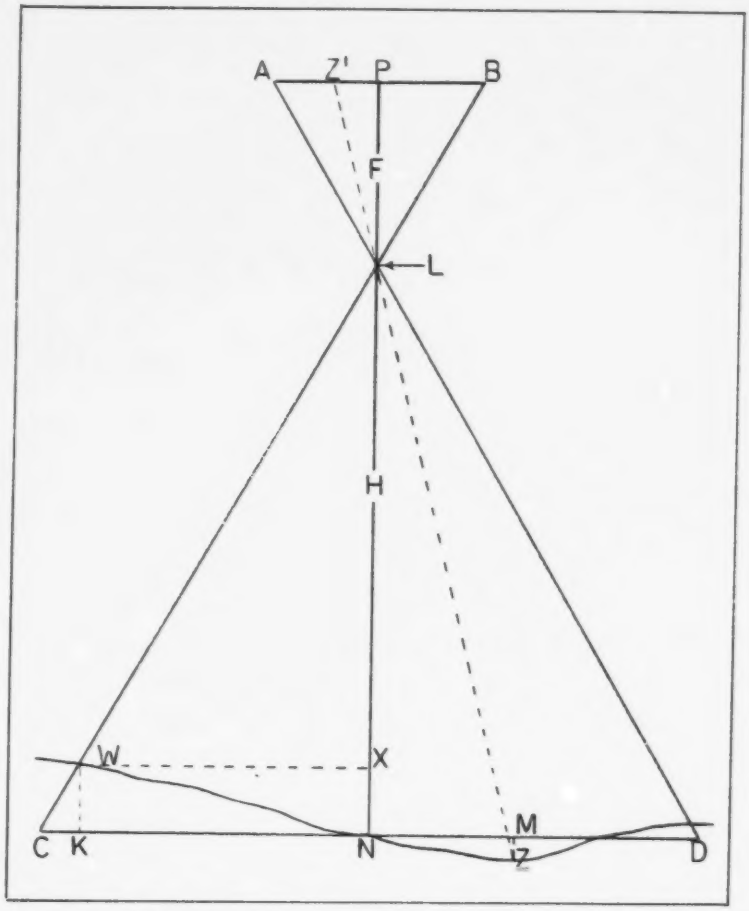
Aerial photography is classified as "large" or "small" scale, depending upon the proportional size of the images which are produced compared to the actual size of the features which they record. No firm differentiation has been made between large and small scale photography, however, scales larger than 1/10,000 are usually considered to be "large scale," and scales smaller than 1/10,000, "small scale." Most 35mm aerial photography, at contact scale (not enlarged) is "small scale."

When classified on the basis of the wavelengths of the reflected light which created the images, several terms may be used. "Panchromatic" indicates that all wavelengths of electromagnetic energy in the visible portion of the spectrum are represented. "Pan-minus-blue" indicates that panchromatic film was used, but that special filters were used to keep the shorter wavelengths, which appear blue, from reaching the film. "Infrared," when applied to conventional photography, refers to electromagnetic energy whose wavelengths extend from 700 to a maximum of about 1,500 millimicrons. Armed with these basic terms, we can initiate our study of 35mm aerial photography.

Most persons have looked at 35mm color slides, and have examined single photographs taken from the tops of high buildings or the tops of hills. Very few, unfortunately, have experience in stereoscopic study of vertical aerial photography. To most persons, the word "stereoscope" evokes memories of the Gay Nineties.

35mm aerial photography offers many practical advantages. By combined study of vertical aerial photographs, which may be several years old, and projected, recently-obtained 35mm color slides of the same area, changes can be rapidly assessed. Using color slides taken in the fall of the year, when autumn colors are brightest, one can also

FIGURE 1 -- Basic Geometry of a Vertical Aerial Photograph



Although the purpose of this handbook is to help users apply sound, proven photographic and photogrammetric principles so that they might better use 35mm cameras from the air, it is wise to first review the basic geometry of cameras and aerial photography in their least-complicated form -- photographs which are taken with the optical axis of the camera pointed straight toward the center of the earth.

Measurements and calculations of scale, distance, and direction are based on Plane Geometric "similar" triangle relationships -- which state, in effect, that if all included angles in one triangle are the same as (or equal to) all of the included angles in other triangles, the sides and all other straight lines drawn within one of the triangles are proportional to corresponding lines drawn within the other triangles.

In FIGURE 1, triangle ALB is similar to triangle CLD. Line PL, the focal length of the camera (designated F), is proportional to line LN (which is designated H), the flying heighth or distance from the lens of the camera to the point on the ground which is directly in line with the center of the earth and the optical center of the lens. If this distance is known, or can be calculated, straight line distances on the film plane, AB, are directly proportional to corresponding distances on the Ground "Datum" plane, CD.

The basic scale-relationship formula is

F/H = P/D where
F = Focal length of the camera
H = Flight altitude of the aircraft over the datum
P = Measurement on the photograph, and
D = Measurements on the datum

Since the surface of the earth is very rarely perfectly flat, most of the calculated ground distances will have some perspective error -- they will be either a bit longer or shorter than they would be if the ground surface and the datum plane were both flat and coincided perfectly with each other.

In FIGURE 1, the straight line extending from B to C reaches the ground at W, before reaching C. Line WX, then, is shorter than line CN by distance CK. Line Z-Z' crosses the datum plane before reaching the ground, so that point Z is displaced outward (toward D) the distance designated M.

very rapidly assess, for example, the kind and amount of game cover in an area, and the type of tree cover.

A certain amount of geometry has been built into the photographic and flight planning procedures outlined in the following sections. This has been done to permit simple physical measurement, in acres, of the area which is pictured on oblique photographs through use of special perspective grids ("Canadian Grids"). The perspective grids printed in this booklet are scaled for analysis of pictures taken with any good 35mm camera, with a 50mm focal length lens (the most common length).

Any light plane with open cockpits or easily opened windows can be used as a photo plane for hand held oblique aerial photography.

The following sections outline the procedures which are recommended.

II.

PROBLEMS IN AERIAL PHOTOGRAPHY

The most persistent problems in aerial photography arise from the presence of atmospheric haze and aircraft or camera movement.

HAZE

Haze adds non-image-forming light to the image-forming light reflected from ground objects. This tends to lower the apparent contrast of the scene. The effect of haze in obscuring an area being photographed increases with distance. Distance, in this instance, is controlled by flight height, or altitude, and the obliquity of the camera angle. The effects of haze are more pronounced in high oblique photography than they are in low oblique photography. Maximum haze problems are encountered in taking high oblique photography from high altitudes.

AIRCRAFT SPEED

The shutter speed required to stop the apparent motion of the landscape depends on the speed of the aircraft, angle of direction of travel relative to the lens axis, the distance from the camera to the nearest object in the scene, the focal length of the camera, and the degree of enlargement of the final photograph.

While special techniques can be used to reduce the amount of apparent image motion, such as taking pictures at an oblique angle as the aircraft approaches or leaves the areas being photographed, experience has shown that one is more apt to succeed in completely covering an area by taking a series of consecutive overlapping photographs, at right angles to the direction of flight. For this reason, it is desirable to use a shutter speed no longer than 1/250 of a second, even though apparent image movement might be stopped at slower speeds.

TIME OF DAY

Most vertical aerial photography available from commercial and Government sources was deliberately taken between 10 a.m. and 2 p.m. During this period of the day, shadows are shortest. Shadows, particularly in forested areas, are likely to obscure ground details. This is an important consideration in topographic mapping. Since most of the available aerial photography was taken with mapping as either a primary or secondary objective, efforts were deliberately taken to minimize shadows.

Shadow detail may, however, accentuate minute differences in the height of vegetation, creating shadow marks which aid in location of obscure, but important ground features. Examples are minor increases in the height of grass, bushes and trees caused by increased soil fertility or moisture content.

Aerial photography taken early in the morning or late in the afternoons are optimum for recording shadow-accentuated minor features.

Vertical aerial photography of surface water bodies must be taken when the sun is not less than 26° nor more than 50° above the horizon. If the sun is less than 26° or more than 50° above the horizon, sun glare will obliterate all detail on or under the surface of the water.

TIME OF YEAR

Vertical aerial photography intended for photogrammetric mapping is normally taken during the winter. Heavy leaf cover at other times of year obviously obscures the view of the ground from above.

Analysis of vegetation may be very important in certain water resources problems.

Aerial photography taken for interpretation or for illustration may require that deciduous tree cover, aquatic vegetation, crop and grass types be identifiably pictured. Variations in growing rates between different areas may also be critical. Identifiably picturing different types of vegetation is particularly important in assessing mineral content of the soil. One of the best and most obvious indicators of certain types of minerals in the soil are assemblages of botanical indicator plants. A certain type of poppy, for instance, is an indicator of copper in the soil. A type of pansy indicates zinc. More prosaic, but very important, is the accepted fact that the presence of most species of pines indicates sand and gravel, or at least well-drained, coarser-grained soil.

If terrain analysis "indicators" of this sort are to be studied or illustrated, quite obviously the necessary aerial photography must be taken during those months when many natural features stand in sharpest contrast to their backgrounds.

In the northern hemisphere, April is a critical month in the assessment of variations in soil fertility by photographic interpretation. During this month, the growth of vegetation is apt to be accelerated in more fertile areas in contrast with areas which are too wet, too dry or less fertile.

Aquatic vegetation is usually most dense in the middle and late summer months. Surface waters are less apt to be clear during this period, due to increased biotic activity. This may restrict penetration of light into water masses, prohibiting photography of subsurface detail. In contrast, heated or warm water is less dense than cool water. Consequently light entering this water is not refracted as sharply as it is in cooler water. As a result, if the water color level and the "water clarity" -- which is reduced by turbidity traceable to biotic activity, suspended sediments, and dissolved solids in solution -- are such as to permit deep penetration of light into the water and out again, small features can be pictured to much greater depths during the summer months.

Fall colors may be very helpful in delineating different types of vegetation. Many types of green vegetation reflect almost the same shades of green during the summer months. A soft maple growing next to a basswood may appear to reflect almost the same shade of green in the summer. In the fall, however, the maple may be a brilliant red, while the basswood has turned yellow.

After the leaves have fallen in the winter, pines, spruces, cedars and other conifers stand in stark contrast to the bare limbs of elms, maples and other deciduous hardwoods.

As was stated, the pines, white spruces and often cedars indicate permeable, well-drained soils.

For detailed aerial photographic interpretation analyses, aerial photography should be taken during all four seasons.

EFFECTS OF CLOUD COVER AND SURFACE WINDS

Best results are normally obtained on relatively clear days, following a light rainfall, particularly under a high, thin layer of clouds.

A light rain tends to wash the dust from the air. In addition, if the ground is still damp, minor terrain features are enhanced. A light rain also tends to wash dust from vegetation and grass, so that reflectance variations characteristic of different types are more clearly visible.

Light surface winds are sometimes helpful in accentuating tonal variations in vegetation. Striking contrasts are sometimes observed between trees and lower vegetation, when the still vegetation is disturbed by a light breeze.

A light breeze also appears to accentuate the appearance of heated coolant water or "thermal pollution" flows in lakes and streams. It is believed that this is caused by variations in density of the water.

III.

EQUIPMENT AND OPERATIONS

CAMERA EQUIPMENT

Any good 35mm camera can be used. It is suggested that the camera be one equipped with a rapid advance lever, or that an automatic camera, such as the Eastman Motormatic be used. FIGURE 2 illustrates the Eastman Motormatic. This will simplify the advance of film between exposures.

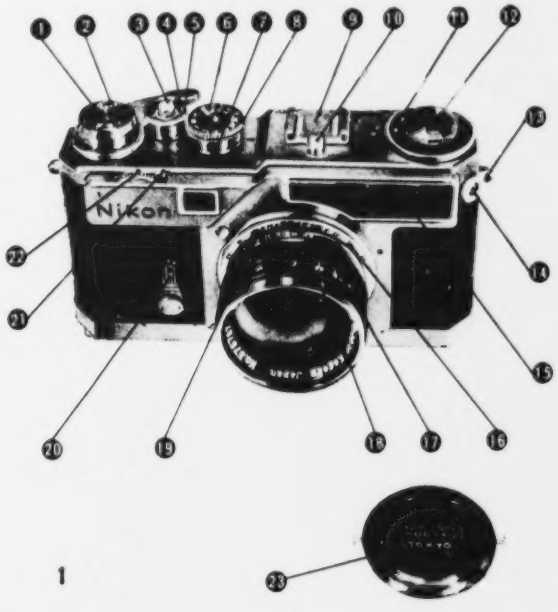
FIGURE 2 -- Eastman Kodak Motormatic cameras are fully automatic. Film advance is powered by a spring motor which advances the film immediately after the shutter closes. Full winding provides power for 10 exposures. Aperture settings are automatically adjusted by a built-in light metering system. User adjustments are simplified to shutter speed, rated film speed, and focus -- the camera does the rest.

A single lens reflex camera is easier to use, under most conditions. One is less apt to include a strut or part of the wing of the plane in the format. Single lens reflex cameras cannot be used to take infrared photography, usually, because one cannot see through true infrared filters. Cameras having separate rangefinder/viewfinders are easier to use with infrared and other special filters, because the filter will not block the view of the area being photographed. FIGURES 3 and 4 illustrate some of the differences between Range-Finder and Single Lens Reflex cameras.

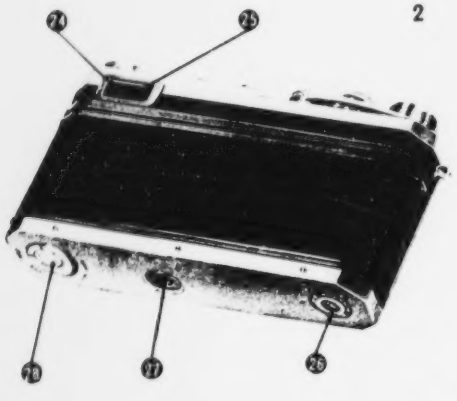
A stereo lens such as the Nikon lens shown in FIGURE 5 offers special advantages for taking 35mm photography from the air. This is true because as is illustrated in FIGURE 6, a stereo lens can be used to take "multiband"

Front View

1. Automatic exposure counter
2. Film load reminder
3. Shutter release button (with screw thread for attaching cable release)
4. Single stroke film advance lever
5. AR ring, for setting film advance (A) and film rewind (R)
6. Shutter speed selector dial
7. Synchro indicator for flash synchronization
8. Synchro selector for flash synchronization control
9. Accessory shoe
10. Electric contact for cordless flash gun
11. Lens field selector
12. Film rewinding crank
13. Eyelet for neck strap
14. Terminal for flash and electronic flash
15. Combined view-and range-finder window
16. Depth of field scale
17. Spring catch for lens
18. Lens aperture (f-number) set ring
19. Distance scale
20. Self-timer
21. Infinity lock for focusing wheel
22. Focusing wheel
23. Snap-on lens cap



1



2

Rear View

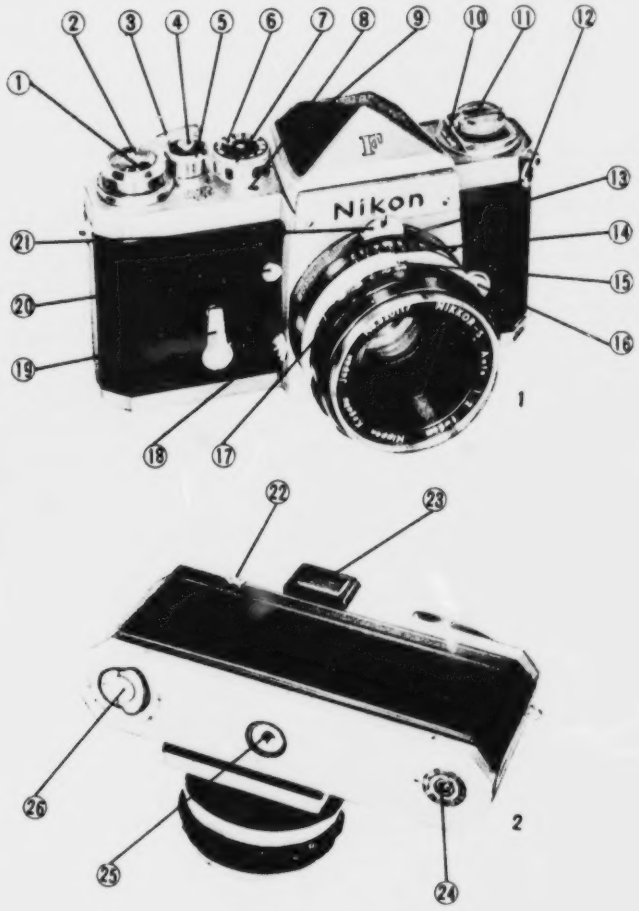
24. Additional view finder eyepiece for 28mm and 35mm wide-angle lenses
25. Eyepiece for combined view-and range-finder
26. Film type (ASA speed) remin ler dial
27. Tripod socket
28. Lock for removing and replacing camera back

FIGURE 3

aerial photography. "Multiband" aerial photography, as used here, consists of two photographs of the same area taken at the same time, side by side, but each exposed through a different filter. The different contrasts exhibited by the same objects in the two photographs are often very helpful in analysis or interpretation.

FILTERS

Most aerial photography is obtained using filters, which reduce the effects of atmospheric haze. Haze is always present in varying amounts, depending upon local weather conditions, proximity to urban areas, altitude and numerous other factors. Haze results from the scattering of light



Front View

1. Automatic exposure counter
2. Film load reminder
3. Single stroke film advance lever
4. Shutter release button (with screw thread for attaching cable release)
5. A-R ring for setting film advance (A) and film rewind (R)
6. Shutter speed selector dial
7. Synchro selector for flash synchronization control
8. Synchro indicator for flash synchronization
9. Eye-level view finder
10. Accessory shoe
11. Film rewinding knob with lifting up crank
12. Terminal for flash and electronic flash
13. Lens aperture (F-number) preselect ring
14. Aperture index dot
15. Distance index with depth of field scale
16. Lens detaching button
17. Focusing ring of lens with distance scale
18. Mirror locking knob
19. Self-timer
20. Depth-of-field preview control
21. Diaphragm nail to be coupled to exposure meter

Rear View

22. Release button for detaching the view finder
23. Finder eyepiece window
24. Film type (ASA speed) reminder dial
25. Tripod socket
26. Lock for removing and replacing camera back

FIGURE 4

by very small dust particles and water vapor in the air, and to some extent, by the air itself. Ultraviolet and blue light, being of relatively short wavelength, are scattered more than green or red light. Consequently, filters which block passage of ultraviolet and blue light, while allowing the longer wavelengths to pass, will reduce the bright haze light or brightness flux. If filters are not used, the brightness flux may obscure features which one wishes to photograph.

In the case of black-and-white negatives or transparencies, yellow filters are usually used to reduce the effects of haze. Under severe haze conditions, orange and red filters may be required.

Filters can also serve a second purpose. They may be used to increase the contrast between objects within the photographed scene. Without a filter, for instance, a red apple on a tree might photograph the same shade of gray as the leaves which surround it. Using a red (Wratten 25(A)) filter, which transmits the red light reflected from the apple, but absorbs the green light reflected from the leaves, the apple would photograph very light gray against a very dark, almost black background. The same general result can

FIGURE 5: Both Nikon and Leitz (Leica Camera Manufacturer) produce 35mm stereo lenses which place conjugate images side-by-side on a standard 35mm format. These lens systems consist of two lenses which are positioned 18mm apart in the same lens barrel. A septum (dividing wall) extends toward the film between the two lenses, so that the images will not overlap.

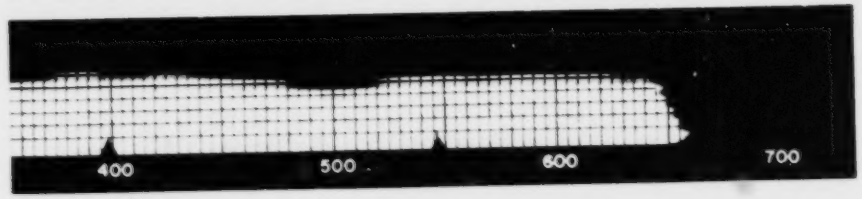
A detachable prism system increases the effective distance between the two lenses. The increased parallax allows stereo effects to be recovered when these lenses are used at distances up to about 1,800 feet.

This type of lens system may be used to take "multi-band" photography by placing different filters over each lens.

The camera illustrated in this figure is a Nikon S-2 with a Nikon stereo lens in position. The prism system and special view finder are to the left of the camera body. A standard 50mm lens (f/1.4) with sunshade and lens cap are to the right.

TYPE 131—CRONAR® Rapid Processing Aerial Negative

COLOR SENSITIVITY: Panchromatic



Equal Energy Spectrogram

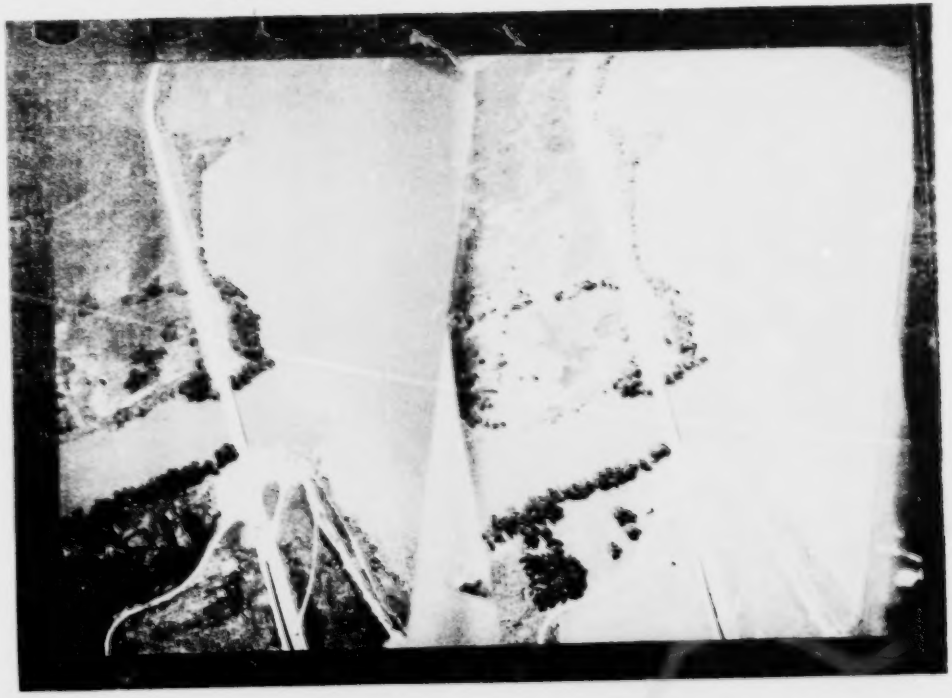


FIGURE 6

This multi-band stereogram illustrates the sharpened tonal contracts which are achieved through the use of aerial stereo-multiband techniques. In addition to sharpening contrasts in the individual photographs, the appearance of some of the imagery is further accentuated by binocular reinforcement in stereo study -- images seen with the right eye are reinforced by images seen with the left eye, stereoscopically.

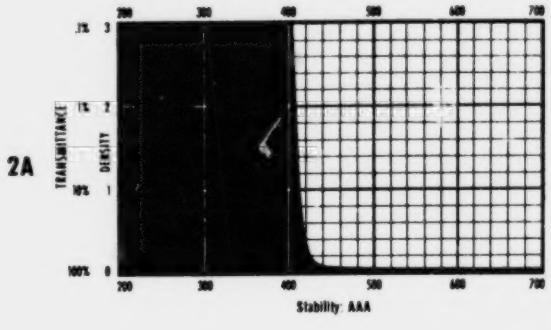
The film acceptance curve of the type of film used, and the transmission diagrams of each filter appear above the stereogram. As shown, the Wratten 26 passes only that part of the visible spectrum in which the wavelengths are longer than 590 millimicrons. The left Wratten 55 passes the band between 460 and 590 millimicrons. The paired combination, then, is almost mutually exclusive.

The striking contrast in appearance between that part of the water flowing from the outfall along the shore toward the lower right and the rest of the water mass is caused by a different wave form which was observed in the surface layer of heated coolant water. In this instance the green filter (Wratten 55) yields greater tonal contrast.

be achieved from the air, if one knows the background spectral reflectance of the area to be photographed, and the specific reflectance of features which are to be accentuated.

Filters are also valuable as aids in photographing underwater features. Maximum penetration of clear sea water requires that a filter which transmits green light, the wavelengths of which extend from 460 to 540 millimicrons, be used. Maximum penetration of usually more turbid fresh water, requires that a filter which transmits yellow-orange light, the wavelengths of which extend from 576 to 609 millimicrons, be used.

A filter corresponding to a Wratten 2A (see FIGURE 7) is recommended for use with color film. Since color films are panchromatic (i.e., sensitive to "all colors" of the visible spectrum), the blue portion of the visible spectrum must be included in the picture to image both blue images, and to help create the rest of the colors in the visible spectrum, but the ultraviolet and other wavelengths outside the visible spectrum should be filtered out. One may, of course, use color filters with color film to create special effects. Such special effects may help to accentuate specific imagery.



Dominant Wave Lgth.	(A)	579.5
Excitation Purity	(A)	7.0
% Luminous Transmit.	(A)	90.5
x_A		0.4519
y_A		0.4131
Dominant Wave Lgth.	(C)	568.6
Excitation Purity	(C)	6.0
% Luminous Transmit.	(C)	90.3
x_C		0.3177
y_C		0.3310

WAVE LENGTHS
(in Millimicrons)

Percentage of Transmission

	400	500	600	700
00	--	89.7	90.8	
10	4.0	90.0	90.8	
20	42.0	90.2	90.9	
30	74.0	90.3	90.9	
40	82.7	90.4	90.9	
50	85.6	90.5	91.0	
60	87.0	90.6	91.0	
70	88.1	90.6	91.0	
80	88.8	90.7	91.1	
90	89.4	90.7	91.1	

Not listed

FIGURE 7

When infrared film is used with an infrared filter the contrast between images is usually further increased by two factors. First, object reflection differences are usually greater in the infrared region; and, secondly, there is less scattering of reflected light of these longer wavelengths in passing from objects on the ground to the camera. This helps reduce the effect of haze.

All but a very few filters absorb some of the available light, consequently, the amount of exposure must be increased when filters are used. This is done by either using a slower shutter speed or by increasing the aperture setting of the camera, so that more light can reach the film in the same period of time. The amount of increase necessary for each filter is known as its "filter factor." The filter factor depends not only on the amount of light absorbed by the filter, but upon the spectral sensitivity of the film and spectral quality of the light.

Filter factors are listed on the film-data sheets, which are packed with each roll of film, are to be used as guides. The actual filter factor depends on the prevailing light and the general color of the subjects to be photographed.

For further information in photographic filters, the Eastman Kodak Scientific and Technical Data Book, "Kodak Wratten Filters" should be consulted.

It is suggested that a polarizing filter be used, particularly when the scene to be photographed includes a body of water of a flowing stream.

Polarizing filters reduce scattered light, and sometimes reduce glare from bright waves and ripples. This glare tends to destroy tonal variations in water masses, which may be significant.

Polarizing filters also reduce the passage of light, necessitating that exposure be increased.

The appropriate filter factor is marked on each filter.

FILM REQUIREMENTS

Any moderately fast ultra fine-grained color, panchromatic or infrared film can be used from the air. These general requirements stem from the facts that (a) fast shutter speeds must be used to stop apparent image motion, induced by the speed of the aircraft. (b) one must picture small images clearly, and (c) haze, water vapor, and dust in the atmosphere causes blue and ultraviolet light to scatter. The longer wavelength portions of the visible spectrum, and the "near" region of the infrared spectrum, are not as severely affected by these "image degradants" in the atmosphere.

An exception occurs when one wishes to picture contamination in the air. Then "short-wavelength" film and filter combinations should be used.

RECOMMENDED 35MM FILM AND FILTER COMBINATIONS

Certain 35mm film and filter combinations have yielded consistently good results from the air. Some of these are listed below:

COLOR FILMS

For most purposes, Eastman Kodak Kodachrome (both Kodachrome II and Kodachrome X) has given the best results for initial reconnaissance of an area. Color aerial photography discloses many slight variations in the color of soils, vegetation, and in water which may indicate the presence of polluting substances. Many of these minor color variations might be lost in the gray tones of black and white photography. It has been found in studies of human vision that the human eye-brain combination is capable of "seeing" about 128 different shades of gray, but that thousands of different colors can be seen.

The Kodachromes are moderately fast, extremely fine grained color films. It is recommended that they be exposed through a Wratten 2A (or equivalent) filter, and that they be slightly underexposed from the manufacturers' recommended speed. Kodachrome II for instance, appears to yield better results when exposed from the air at ASA 32, rather than at the recommended speed of ASA 25. Slight underexposure appears to yield better color saturation, so that small differences in color stand out more clearly.

Kodachrome must be commercially processed.

Color negative films, such as Eastman Kodak Kodacolor offer unique advantages, in that both black and white and color prints can be made from the same negative. This advantage has been particularly helpful with both measurements and information are to be obtained from the same picture. Important color difference boundaries, measurement reference lines, and other details can be marked directly onto the black and white print, based on analyses made of the color prints. This has been particularly helpful in analyses of direct stereograms, made by 3.32 enlargements of pictures taken with a stereolens, such as the Nikon or Leica.

BLACK AND WHITE FILMS

Black and white films are recommended when the pictures are to be used for illustration, specifically for measurement, or when special filters are to be used to make certain shades of gray stand out more clearly than others.

A black and white film and filter combination which has yielded consistently good results, particularly when the picture has included a body of water, has been Eastman Kodak Panatomic-X, exposed through Wratten 16 filter (FIGURE 8). Best results have been obtained with this combination when it has been exposed at ASA 250, and processed in Diafine, a special custom developer.

INFRARED FILMS

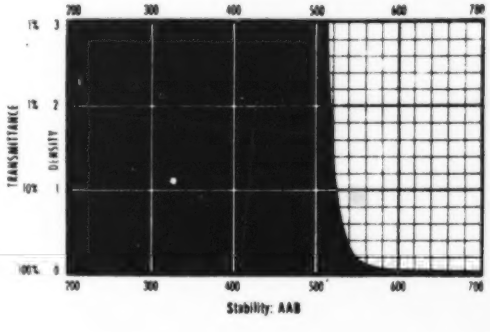
Excellent results have been obtained with Eastman Kodak Infrared film, exposed through a Wratten 25 (A) filter (FIGURE 9), at the standard exposure of f/2, 1/500 of a second. This standard exposure is recommended because most light meters are not sensitive to infrared light, which prevents measurement of prevailing light values at the time of exposure. Fortunately, it has been found that the amount of infrared light does not vary as much as does the amount of visible light, so that a standard exposure which is suitable for use from the air between the hours of 9 a.m. and 4 p.m. during good flying weather could be developed.

When exposed as recommended, finest grained results with infrared film have been obtained when the film has been processed in Eastman Microdol-X developer, diluted 1:3 with distilled water, for 25 minutes.

Infrared color film is also available, but currently only in widths for use in large aerial cameras. This film could be made available for 35mm use, but only if very large quantities were ordered. Eastman Kodak Ektachrome Infrared Aero (Process E-3) film was developed for military use, for detection of camouflaged military installations and equipment. With this film, healthy vegetation appears magenta, while wilted or diseased vegetation appears cyan (blue-green). Camouflage Detection Film (as this film is usually called) may be very helpful for tracking down the sources of contaminating substances in streams, particularly if the substance attacks aquatic plant life.

When any of the infrared films are used, the camera must be focused at "infrared infinity" (about 57 feet with a 50mm lens) if ground details are to be in sharp focus, rather than "normal" infinity as is required when panchromatic films are used from the air.

Dominant Wave Lgth.	(A)	588.7
Excitation Purity	(A)	99.0
% Luminous Transmit.	(A)	67.9
x_A		0.5667
y_A		0.4314
Dominant Wave Lgth.	(C)	582.7
Excitation Purity	(C)	99.4
% Luminous Transmit.	(C)	57.7
x_C		0.5289
y_C		0.4684



16

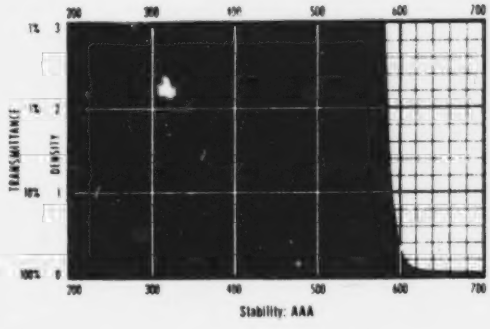
WAVE LENGTHS
(in Millimicrons)

	Percentage of Transmission			
	400	500	600	700
00	--	--	89.0	90.8
10	--	--	89.6	
20	--	3.0	90.0	
30	--	22.0	90.2	
40	--	48.0	90.3	
50	--	69.5	90.4	
60	--	79.5	90.5	
70	--	84.0	90.6	
80	--	86.3	90.7	
90	--	87.8	90.8	

Not listed

FIGURE 8

Dominant Wave Lgth.	(A)	617.2
Excitation Purity	(A)	100.0
% Luminous Transmit.	(A)	22.5
x_A		0.6850
y_A		0.3147
Dominant Wave Lgth.	(C)	615.3
Excitation Purity	(C)	100.0
% Luminous Transmit.	(C)	14.0
x_C		0.6808
y_C		0.3190



25
(A)

WAVE LENGTHS
(in Millimicrons)

	Percentage of Transmission			
	400	500	600	700
00	--	--	50.0	89.5
10	--	--	75.0	
20	--	--	82.6	
30	--	--	85.5	
40	--	--	86.7	
50	--	--	87.6	
60	--	--	88.2	
70	--	--	88.5	
80	--	--	89.0	
90	--	12.6	89.3	

Not listed

FIGURE 9

PROPER EXPOSURE SETTINGS

As a rule of thumb only about 1/4 as much light in the clear, relatively dust-free air above us is required to yield good aerial photographs as is required on the ground.

To implement this rule of thumb, it is recommended that one use a light meter on the ground to measure the proper exposure for the rated film speed of the film at the fast shutter speeds required, adjust for the appropriate filter, then "stop down" two full stops.

For instance, if the proper exposure measured prior to a flight is f/5.6 at 1/500 of a second, and a wratten number 16 filter (filter factor 3) is being used, the recommended camera setting for use in the air is f/6.3 at 1/500 of a second. One arrives at this setting by "opening up" the aperture from f/5.6, to half-way between f/2.8 and f/4, then "stopping down" the equivalent of two full stops. f/6.3 is half-way between f/5.6 and f/8.

PILOT AND AIRCRAFT

Any high-wing monoplane can be used as a photo plane for obtaining the types of oblique aerial photography outlined in this booklet -- provided that a window can be opened. Unless the photographer is the pilot, it is very desirable that the right window be capable of being opened.

Most of the suitable light aircraft have "side-by-side" seating. The pilot flies the plane from the left side and the passenger-photographer sits on the pilot's right.

The two most popular light aircraft, based on the number in use throughout the United States, are the Cessna 150 and 172. Both windows of the 150 can be conveniently opened. Many 172's have been modified so that the right window can be opened, although as manufactured, only the window on the pilot's side (left) can be opened. The wings of either model are supported by a single strut, consequently, there is little chance that a strut will accidentally block part of the area which is to be photographed.

Using the procedures outlined in this booklet, the Cessna 150 is an ideal light plane for aerial observation and 35mm, hand-held aerial photography.

Special doors, called "Patroller" doors, are available for the 150. Patroller doors, which have large transparent panels in them, were developed for pipeline and power transmission line patrol work. Both the pilot and observer have excellent visibility through the panels in the doors. The Cessna 150 equipped with Patroller doors is shown in FIGURE 10.

Civilian flying services are available by the hour at most local airports. The airport manager will be glad to assist in obtaining these services.

Federal and local government agencies may arrange for flying services by contacting the Civil Air Patrol. The Civil Air Patrol is a Volunteer Auxiliary of the U.S. Air Force, with active units in each of the 50 States. The Commanding Officer of the nearest Civil Air Patrol Squadron can be contacted through the local Air Force Recruiting Office.

PRE-FLIGHT CONSIDERATIONS

Commercial 35mm film is spooled in 20 and 36 exposure cartridges. It is recommended that individual sets of consecutive overlapping pictures -- or "flight lines" -- consisting of 10 or 18 consecutive exposures be used in 35mm aerial photography. Each photograph along the line of major interest should overlap the one which preceded it by 60%. Sets of 10 or 18 consecutive exposures are recommended so that one can cover an area with a low oblique series, circle, and cover the same area with a high oblique series, all on the same roll of film.

The ground area covered by each 45° oblique taken from an altitude of 1,500 feet, using a 35mm camera with a 50mm lens, is approximately 50 acres. The centerline trace for 10 consecutive exposures with 60% overlap is approximately 1.2 miles in length. On a USGS 7-1/2 minute map (scale 1/24,000), the line drawn to mark the centerline trace is 3.2

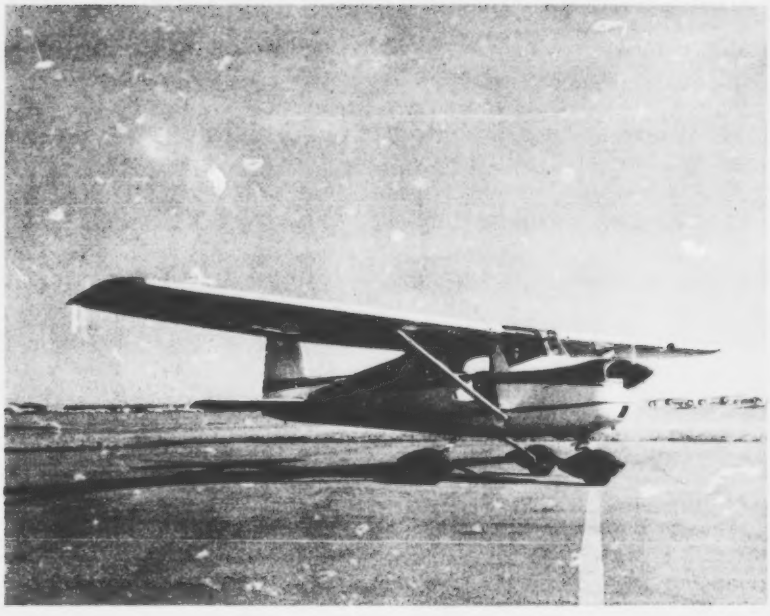
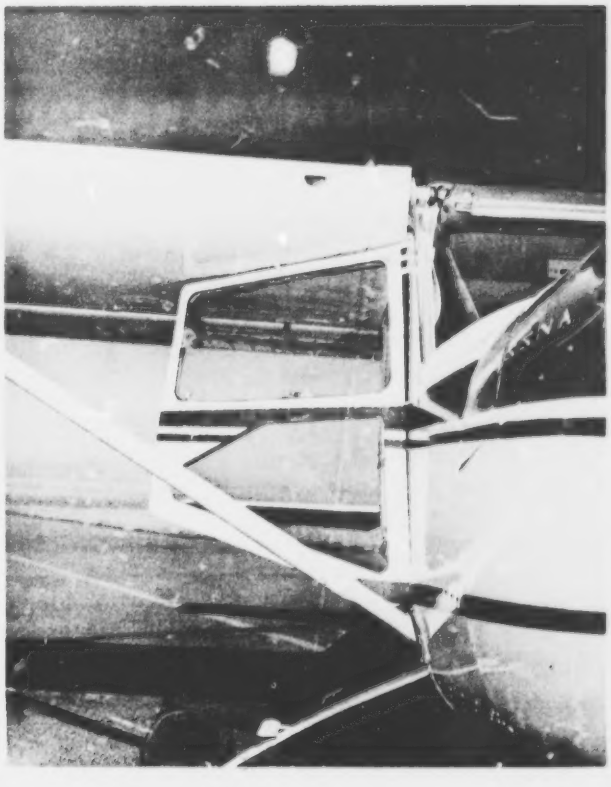


FIGURE 10 -- A Cessna 150 with "patroller" doors is illustrated in these two photographs. Patroller doors were designed for pipe and power line patrolling, and permit excellent observation of the ground to within about 15 degrees of flight path.

The Cessna 150 is an ideal aircraft for taking the kind of aerial photography outlined in this Handbook since both windows can be opened wide. When cruising at 115 miles per hour, the slipstream will hold the windows up against the under surface of the wings when the support bracket is unfastened. When fitted with "Patroller" doors, the pilot can follow a predetermined flight line very accurately.

The wide visibility is also excellent for assessment of the extent of fish kills, following the course of floats, and similar missions.



inches in length. The centerline trace for 18 consecutive exposures (with 60% overlap and taken at a 45° camera angle) covers a distance of approximately 2.1 miles. On a USGS 7-1/2' map, the centerline trace is approximately 5.1 inches in length.

Each horizon trace high oblique photograph covers an area of about 965 acres. The centerline trace for 10 consecutive 60% overlapping "horizon trace" 35mm high oblique photographs, with 60% overlap and exposed from an altitute of 1,500 feet above target area elevation is approximately 4 miles long. The centerline trace for 18 consecutive "horizon trace" high oblique exposures is approximately 6.4 miles long.

High oblique aerial photography is recommended when a relatively large area is to be pictured. It is particularly recommended when no large scale topographic maps of the area are available. As a general rule, it is easier to measure distances and areas in high oblique photography, because the horizon is visible. FIGURE 11 illustrates the geometry of a high oblique photograph.

Low oblique aerial photography, except when taken using "built in" geometric principles presented in the next section, is harder to analyze. This is true because the horizon is not included in the photograph for reference. FIGURE 12 illustrates the geometry of 45° low oblique photography. Specific details are usually easier to identify in low oblique photography and the area covered in each picture is smaller. With practice, 45° low obliques are easier to take.

Two simplified techniques are recommended, i.e., a "Low Oblique" 45° procedure and a "horizon trace" high oblique procedure. Since the geometric angles remain the same, regardless of altitude, the 45° low oblique procedure is more versatile. "Horizon Trace" high oblique photographs are taken so that the horizon is barely visible in the top of the picture. When precisely taken from the recommended altitude of 1,500 feet, the included depression angle is 13° 47'.

FLIGHT PLANNING

Flight planning includes the following steps: (1) Determining the limits of the area to be photographed; (2) determining the flight course to be followed, so that the area can be pictured; (3) selecting the optimum altitude over the ground for the photographic flight; (4) determining the time in seconds between individual exposures, so that consecutive pictures will overlap properly; and (5) calculating the course to be flown to the target area, and the time required to fly from the "home" airport to the target area.

The "built-in" high oblique geometry recommended is based on an altitude of 1,500 feet above the elevation of the ground in the target area.

The minimum equipment needed for flight planning includes a "Sectional" Aeronautical Chart and a Navigational Plotter. Larger scale maps are desirable and the USGS 15' quandrangles are perhaps most suitable.

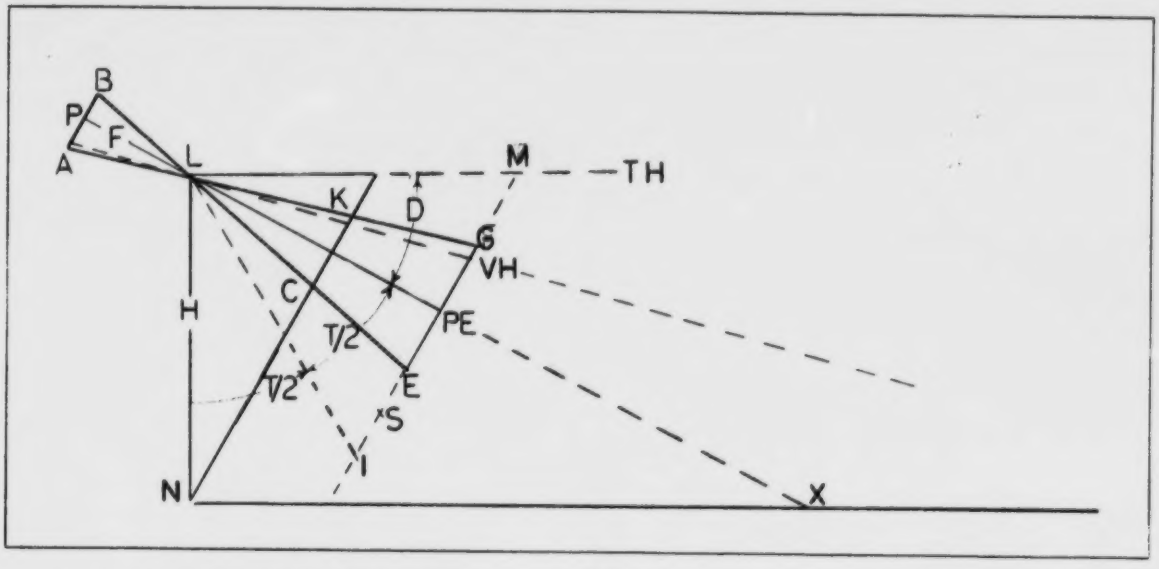


FIGURE 11 illustrates the geometry of a high oblique 35mm aerial photograph which has been enlarged. To help explain the similarities and differences between an oblique and a vertical photograph, the same letters have been used to designate common elements (refer to FIGURE 1).

Triangles ALB and CLK are congruent; that is, all sides and angles in one correspond exactly with the sides and angles of the other, when properly oriented. Triangle ALB represents conditions inside the camera when the picture was taken, with line AB showing the position of the film plane. If the picture were printed the same size as the negative, line CK would represent the plane of the print. Since the picture has been enlarged, line EG represents the plane of the picture. Triangle ELG is similar to triangle CLK, so that the size of all measurements made on plane EG are larger in direct proportion than would corresponding measurements be on plane CK.

In a high oblique photograph, the visible horizon (VH) can be seen. TH represents the true horizon, which is located $\sqrt{H}$ minutes of angle above the visible horizon. In the drawing, this angle is represented as the included angle VH-L-TH. The full depression angle at which the picture was taken is represented by the included angle PE-L-TH. When the full depression angle is subtracted from 90°, the remaining angle is the tilt angle. The Isoscale point, I, is found by dividing the tilt angle by 2 (T/2), and extending a bisecting line until it crosses line EG, which has been extended beyond the limits of the picture itself. After I has been located, the line IG is extended until it intersects TH at M. This line represents Principal Line of the enlarged photograph.

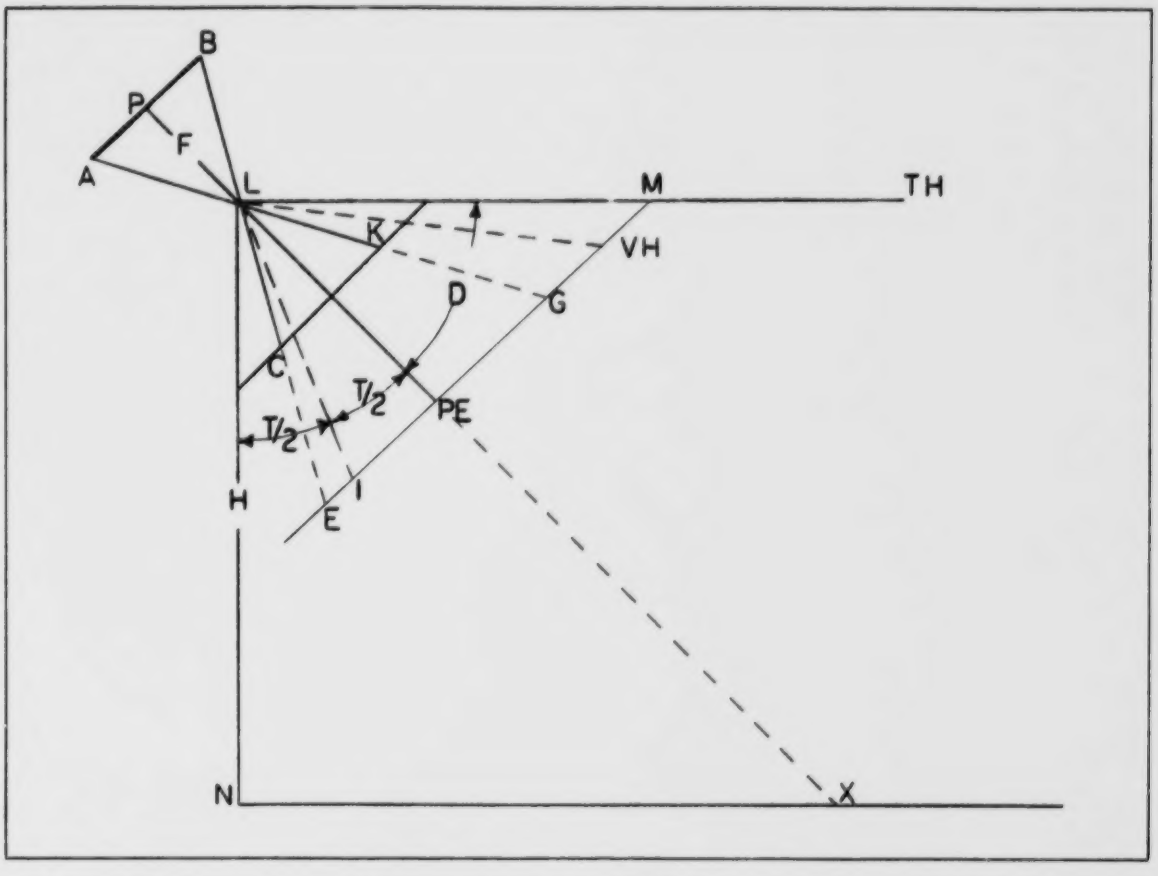


FIGURE 12 illustrates the geometry of a 45° low oblique 35mm enlargement.

Triangle ALB illustrates conditions inside the camera, how they are translated onto a print which is the same size as the negative, and subsequently enlarged. Triangle ALB is congruent with triangle CLK and similar to triangle ELG. Line AB represents the film plane within the camera, and line EG represents the plane of the enlarged photograph. Line M represents the principal line of the enlarged photograph. All conditions are the same as in Figure 11, except that the visible horizon VH lies above the format of the picture.

Step Number 1: Draw a line on the map through the center of the area to be photographed. This line is the "photo center line." Determine the length of the photo center line on the ground in feet. Select the point which is to be at the center of the first photograph in the series. Measure and mark off the center points of each additional consecutive picture along the center line of the photo series. Since each picture overlaps the one which preceded it by 60%, the "ground gained forward," between the center points of succeeding pictures is 2,058 feet. This map distance in inches will vary, depending upon the scale of the map being used. With the previously mentioned depression angle of 13° 47', the horizon will be visible in the very top of the view finder -- if the horizon is level.

Step Number 2: Draw a second line on the map parallel to the photo center line, 6,350 feet away, in the direction of the sun at the time of the day selected for the flight. This is done so that the sun will be behind the plane when the photos are taken. This line is the flight line for high oblique photography -- the course to be followed in the air by the pilot at an above-ground altitude of 1,500 feet. Measure length and direction (azimuth) of the line and select ground reference points to aid in insuring that this line is being followed during the actual flight.

In the case of 45° low oblique photography, the flight line is off-set from the photo center line the same distance as the altitude over the ground -- in this case, 1,500 feet.

Step Number 3: Check with the pilot to determine what his estimated ground speed will be along the selected flight line. This speed will be the airspeed (usually the "crusing" speed of the plane) plus or minus the pertinent vector speed of the winds which will be encountered aloft. Having calculated the ground speed which is to be maintained while flying along the photo flight line, the exposure interval must be determined. This is the time in seconds between successive exposures. For instance, if the ground speed is to be 100 miles per hour, the exposure interval will be 14 seconds.

Step Number 4: By examination of the map, determine the actual altitude over the ground. Since these procedures are based on an altitude of 1,500 feet above the average or datum elevation of the area to be photographed, the height over the ground at any given point will be 1,500 feet plus or minus the difference in elevation between the terrain and the datum. This step is primarily a safety precaution, to insure that a safe flight altitude is maintained at all times.

Step Number 5: Determining the flight course and the time enroute to the target area is necessary primarily to insure that one arrives "on station" while the sun is at the preferred angle, for the type of photography which is to be taken. Also, in figuring total fuel consumption, time to return to base is a factor. For some projects, time required to climb to a point 1,500 feet above datum must be considered, e.g., when taking off in a valley (elevation of 160 feet) to photograph mountain lakes having elevation of five to ten thousand feet.

PHOTODATA SHEETS

When all flight planning data have been calculated, a Photo Data Sheet should be prepared for reference during the photo flight, and to be kept as a permanent record with the negatives.

It is particularly desirable to record the date and time when the photography was taken, the film and filter combination which was used, the altitude from which the photographs were taken, the focal length of the lens of the camera, and the general weather conditions.

It is desirable that a mission number be assigned to each roll of film, for reference.

The date is frequently used as the mission number. For instance, Roll number 071262-A might be assigned to the first roll taken on July 12, 1962. Additional rolls taken on July 12, 1962, might be assigned numbers 071262-B, 071262-C, and so forth.

After black and white 35mm aerial photography has been processed, it is desirable to prepare "proof sheets," for reference and for convenient storage of negatives. Negatives are cut into strips of six consecutive exposures. Six such strips (36 exposures) may be printed on a single sheet of 8 x 10 paper, using a Mioplex or similar type print frame.

8 x 10 proof sheets may be punched with a standard three-hole punch, and filed in snap-ring binders. Individual strips of negatives may be slipped into transparent negative files, and filed with the Photo Data Sheet in envelopes stapled to the backs of the proof sheets. FIGURES 13 and 14 illustrate one type of Photo Data Sheet, and a proof sheet.

ROLL NUMBER_____

PHOTOGRAPHIC DATA SHEET

CAMERA BODY TYPE: _____ Serial Number: _____

LENS - type/focal length: _____ Serial Number: _____

FILM Type_____ ASA Rated Speed_____ ASA Taking Speed_____

PURPOSE: _____

LOCATION: _____

	Focus Distance	Shutter Speed	f/#	Filter
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

	Focus Distance	Shutter Speed	f/#	Filter
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				

PROCESSING DATA

Developer_____ Time_____ Temperature_____

Fixer_____ Time_____ Temperature_____

PROOF SHEET DATA

Paper_____ Developer_____ Time_____ Temperature_____

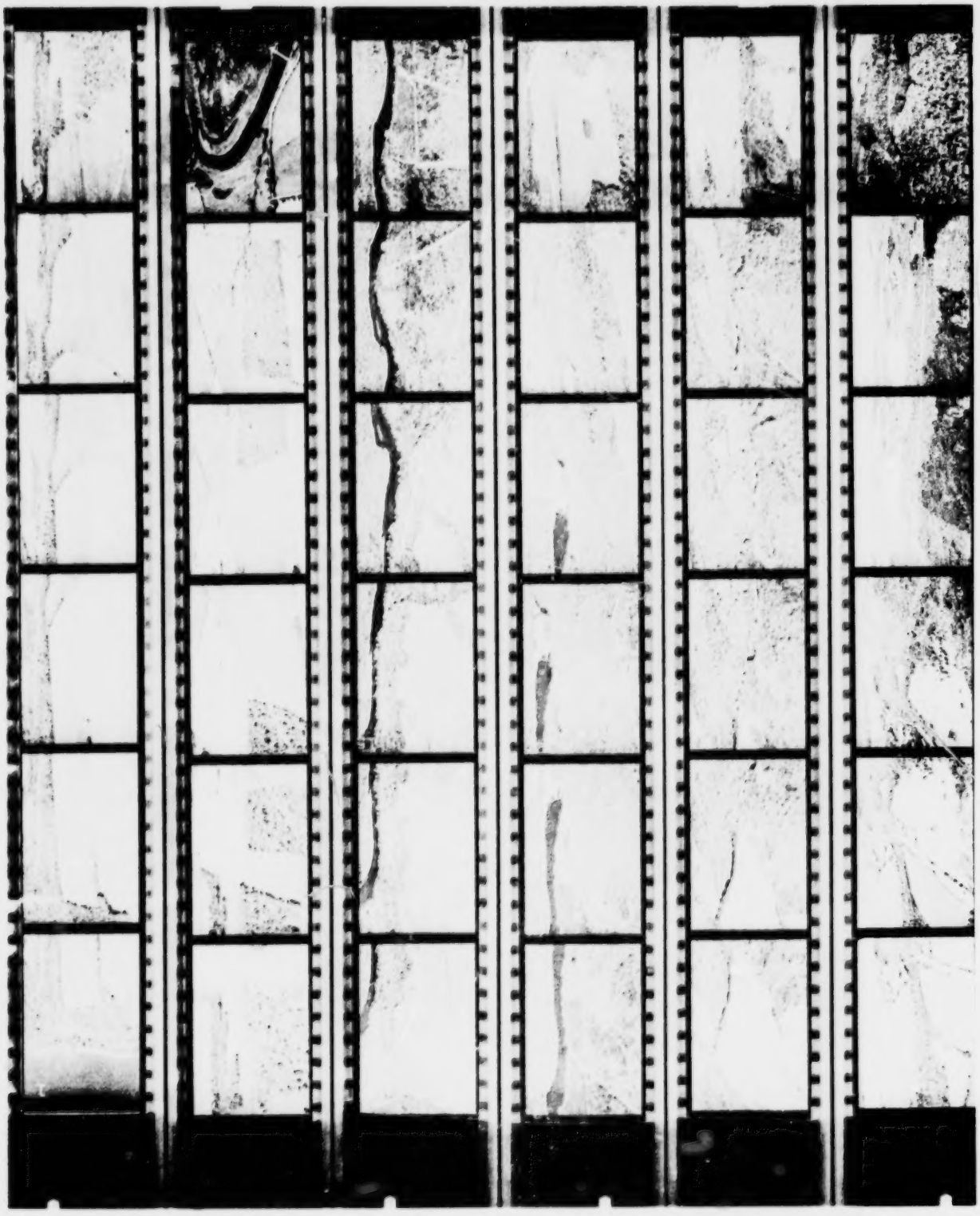
Stop Bath_____ Time_____ Temperature_____

Fixer_____ Time_____ Temperature_____

Hypo Eliminator_____ Time_____ Temperature_____

FIGURE 13

FIGURE 14



IV.

ANALYZING 35MM AERIAL PHOTOGRAPHY

Three fields are covered in this section. The first is the field of physical measurement -- how one can measure ground area, distance, and direction in the 35mm aerial photography which has been taken. The second is a simplified presentation of the techniques of aerial photographic interpretation. The third illustrates a few of the ways in which 35mm aerial photography can be used for illustration, to improve the effectiveness of reports, and for use in presentations before audiences.

MEASUREMENT

The science of physical measurement or calculation of distances in photography is called "photogrammetry."

In this section no attempt will be made to cover the entire field. Only the more basic techniques are presented, and these in "spoon fed" form, with little theoretical explanation of the mathematical concepts which are employed. For more detailed treatment of the field of photogrammetry, the reader is referred to the reference list in the back of this booklet.

Measurements of area, distance and direction in oblique aerial photography require some form of perspective "rectification." Quite obviously, features which were closer to the camera when the photograph was taken appear larger than features which were farther away. When an oblique photograph is rectified, correction factors are calculated and applied so that a uniform scale exists between images, just as if the photograph had been taken straight down, rather than at an angle.

All measurements are theoretically made from the "nadir," i.e., the point on the ground directly beneath the aircraft at the time the picture was taken. More exactly, nadir is that point on the surface of the earth which lies on a straight line from the center of the focal plane of the camera to the center of the earth, assuming that the earth is a perfect sphere.

In rectifying oblique aerial photographs, several points and lines must be located. These points and lines include the "principal point," the "principal line," the "visible" and "true" horizon traces, "nadir," the "isoline" or "isoscale" point, and a "scale" line. Two methods of area measurement are outlined in the following sections. The first method is termed "Graphic Rectification." Graphic rectification techniques can be used for making area, distance and direction measurements from any oblique aerial photograph. The procedures which are outlined include calculation of the geometric properties in the photography.

A second set of simplified techniques, employing perspective grids is also presented. The perspective or "Canadian Grid" techniques are designed to permit direct measurement of area in acres, when photography has been taken following the outlined procedures.

GRAPHIC RECTIFICATION

The techniques outlined in this section are called "graphic rectification," because lines are physically drawn to locate specific points or for orientation.

It is recommended that 35mm oblique aerial photographs which are to be graphically rectified be enlarged to 6 by 9 inch size. A basic point to be remembered in working with enlarged photographs is that enlargement has the same effect as if the pictures had been taken from the same place in the air, but that a longer focal length camera lens had been used. To correct for this increased focal length effect, an "enlargement factor" must be calculated. The enlargement factor is calculated by measuring the length of the format of the enlarged picture in millimeters, and dividing this length by 36. This is done because the format of a 35mm contact print measures 24 by 36 millimeters.

For instance, if a picture has been accurately enlarged to 6 by 9 inch size, the enlargement factor is 25.4 (9) divided by 36, or 6.35.

The following steps in order outline a standard graphic rectification technique:

1. Tape the photograph which is to be rectified to a large sheet of tracing or drawing paper. This is necessary because some of the lines which may have to be drawn are quite long.

2. Locate the "principal point" of the photograph. The principal point is the point approximately in the center of the photography directly in line with the optical center of the lens. It marks the point on the ground where a straight line extended at right angles from the film through the center of the lens would have touched the ground, at the time that the photograph was taken.

   If the camera has been calibrated, a calibration sketch has been prepared which marks the exact location of the principal point. FIGURE 15 is a typical calibration sketch which shows the exact location of the principal point, and the calibrated focal length of a 58mm lens. The data for a 50mm lens would be presented in similar fashion.

   Cameras which are specifically designed for aerial use have small half-arrowheads or crosses located along the edges of the format, called "fiducial marks." Straight lines drawn across the pictures from the fiducial marks intersect at the principal point. Since standard 35mm cameras do not have fiducial marks, an alternative method may have to be used to locate the approximate position of the principal point. The point located when this method is used is not as accurate, usually, but does permit location of relative positions of features on the ground by graphic rectification.

   Photographs in which the approximate principal point is to be found must be enlarged so that the entire format is shown, as in FIGURE 16. The approximate principal point is located at the point where straight lines drawn from opposite corners of the

PHOTOGRAMMETRY, INC.

WASHINGTON-ROCKVILLE INDUSTRIAL PARK ROCKVILLE, MARYLAND WHITEHALL 2-6800

CALIBRATION REPORT
ON
NIKON CAMERA, MODEL F,
SERIAL NO. 6436840
WITH
58 mm, f/1.4,
AUTO NIKKOR-S LENS,
SERIAL NO. 161001

★

Camera calibrated with lens set at f/4 and an ultra-violet filter on Normal Angle Camera Calibrator, Model I. Kodak High Contrast Copy film was developed in D-19 for six minutes at 70° F.

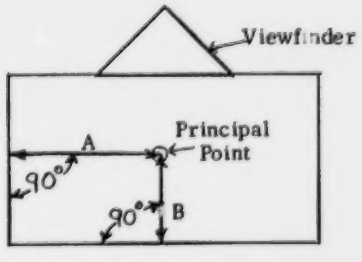
Equivalent focal length 58.00 mm

Half-Angle	Distortion (millimeters)	Radial and Tangential Resolving Power (lines per mm)
0°	0	100
2.5°	0	100
5°	0	100
7.5°	-0.01	100
10°	-0.04	70
12.5°	-0.09	50
15°	-0.19	35

Position of principal point:

A = 17.84 mm

B = 11.77 mm



Focal plane of camera for the purpose of orientation

SERVING SCIENCE THROUGH PHOTOGRAPHIC MEASUREMENTS

FIGURE 15

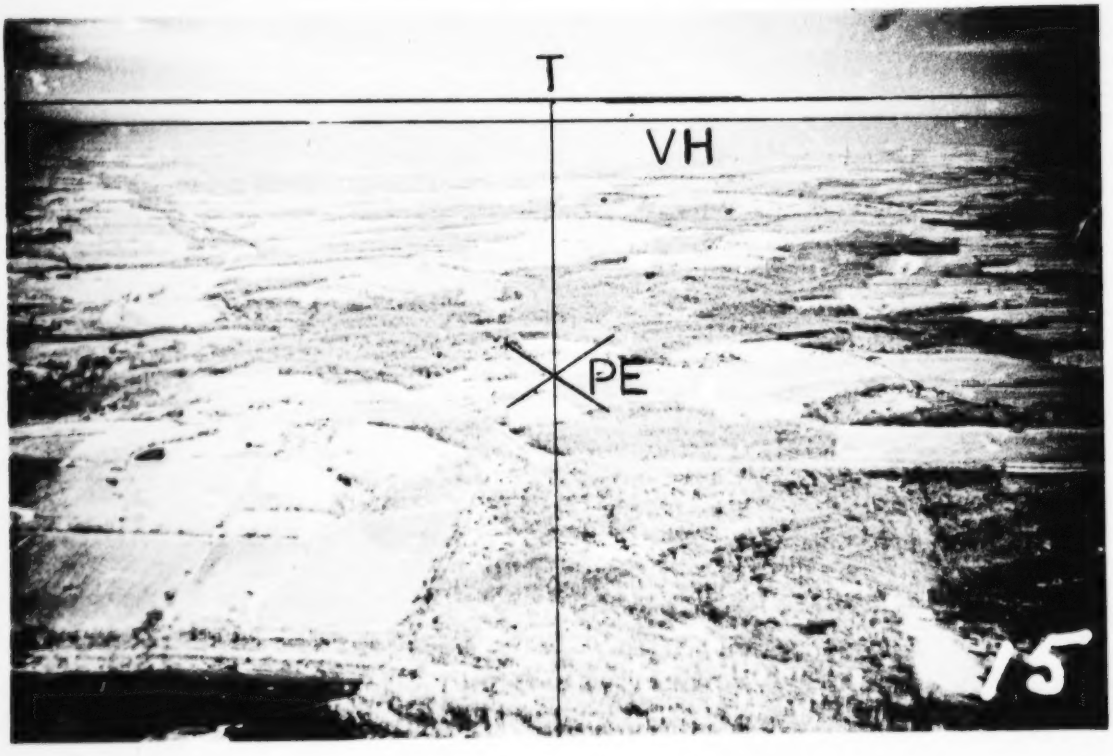


FIGURE 16 -- This 35mm infrared high oblique photograph was taken from an altitude of 1,500 feet. The depression angle is 10° 21'. The camera used was an S2 Nikon with a 50mm lens.

Using the procedures outlined in this Handbook, see if you can (a) construct a perspective grid; (b) graphically rectify the locations of some of the features which are pictured.

picture cross. If the corners of the picture are not square, straight lines may have to be extended along the sides of the picture to create sharp corners.

3. Locate the "visible horizon trace." The visible horizon trace is a line along the horizon which can be seen in a high oblique photograph. For greatest accuracy, the horizon must be level, such as a water horizon. If the horizon is rough or mountainous, or if the photograph is a low oblique, the visible horizon must be found by "vanishing points." Straight parallel lines, such as the edges of rectangular buildings, fences on opposite sides of rectangular fields, and so forth, appear to converge with distance, creating "vanishing points." If two or more rectangular features can be found in the picture so that a vanishing point can be located on each side of the picture, the location of the visible horizon can be found by drawing a straight line connecting the two vanishing points. FIGURE 17 illustrates this condition, and shows how vanishing points can be used to find the position where the visible horizon should be found.

4. Draw in the "Principal Line" of the photograph. The principal line is a line which is drawn at right angles to the visible horizon which passes through the principal point.

5. Calculate the "Depression Angle" of the photograph. The depression angle is the angle down from the true horizon at which the camera was pointed when the picture was taken. The depression angle is the included angle D in FIGURE 18. Two steps are required to find the depression angle:

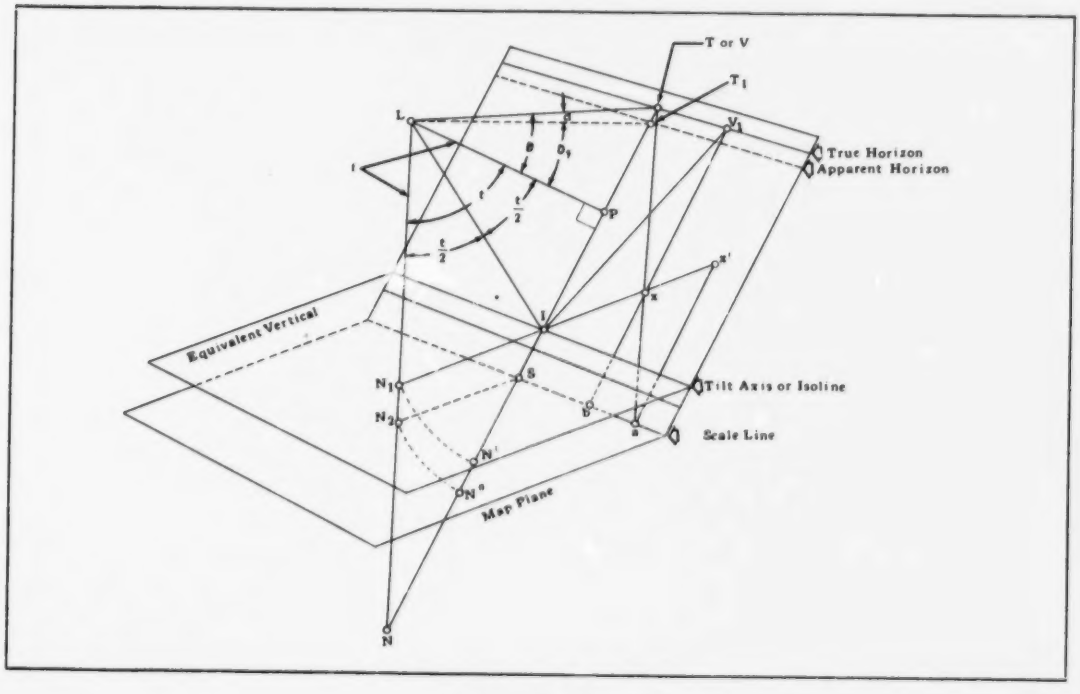


FIGURE 18

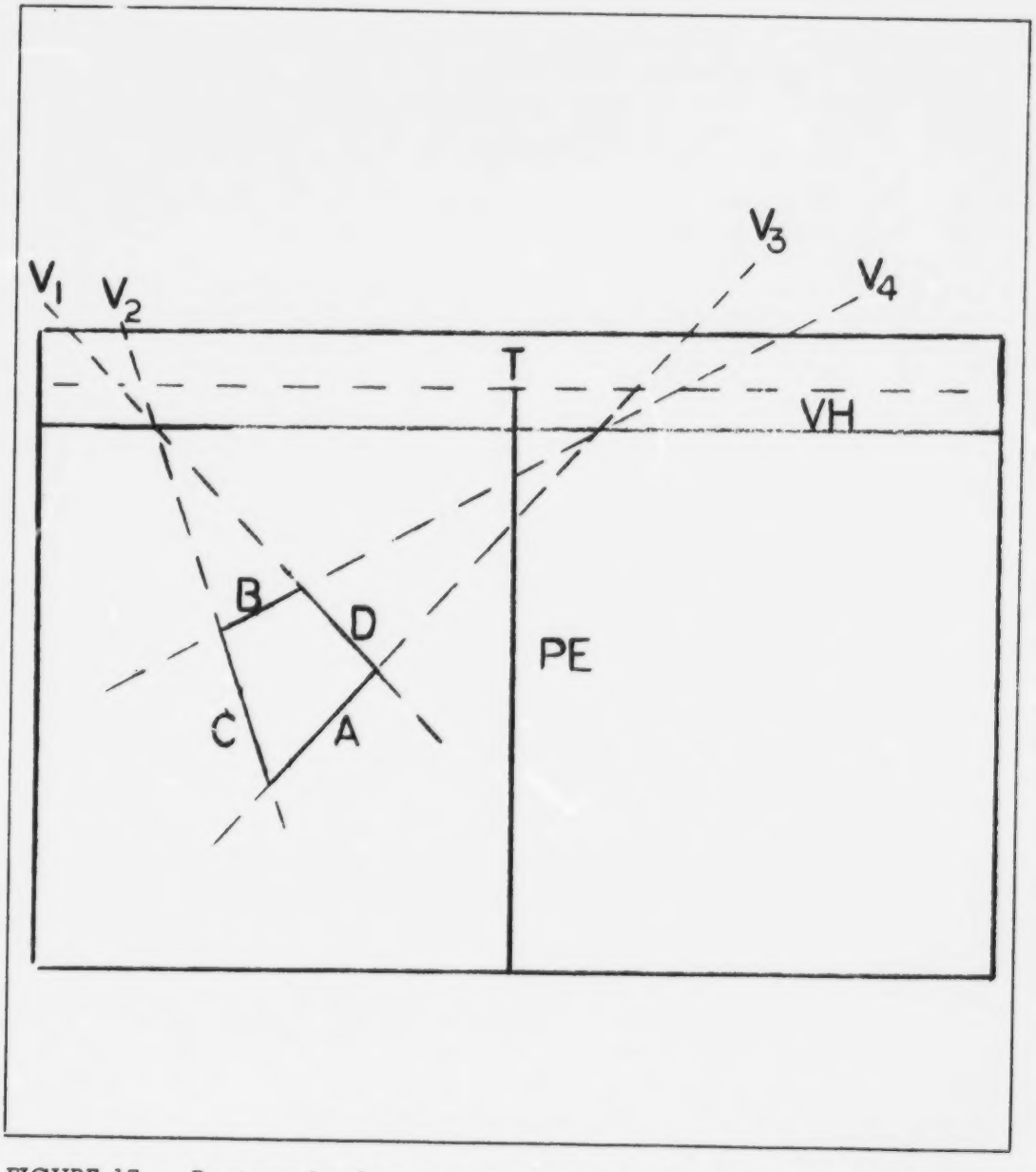


FIGURE 17 -- Rectangular features, such as most buildings and fields appear as irregular four-sided polygons in oblique aerial photography, because of the effects of perspective. When rectified, however, the features again appear rectangular.

If all four corners of such a feature are of the same elevation, vanishing rays extended along the sides cross at the visible horizon. This is sometimes the most effective method for locating the "true" visible horizon even in analysis of a high oblique photograph -- if the horizon which can be seen is rough and mountainous, or obscured by haze.

a. First, the angle at which the camera was depressed below the visible horizon (which was found in Step 3) must be found. This angle is found by dividing the distance from the visible horizon to the principal point by the focal length times its enlargement factor. The answer is the Tangent of the angle. Refer to a set of Trig tables to find the size of the angle, to the nearest second of arc, if possible.

b. Second, find the size of the angle between the visible and the true horizon. This angle acts as a "correction factor" which must be added to the angle found in a. above. This angle is calculated in minutes of arc, by finding the square-root of the flight altitude in feet. For instance, if the angle found in Step a. was found to be 12 degrees, and the photograph was taken from 2,500 feet, the size of the depression angle is 12 degrees plus 50 minutes of arc, or 12° 50'.

6. Find and draw in the "True Horizon." By reference to a set of trig tables, find the tangent of the total depression angle (which was found in Step 5 b.). Multiply the tangent of this angle by the focal length of the camera times its enlargement factor.

   a. Measure up from the principal point the distance found in Step 6 and draw in a line through this point, parallel with the visible horizon.

7. Calculate the "Tilt Angle"; locate and plot the position of the "Isoscale" line and the "Nadir."

   a. Subtract the size of the angle found in Step 5 b. from 90°. The answer is the "Tilt Angle," which also forms a right angle, with P (FIGURE 18) as the included angle.

   b. Locate the Isoscale Point. (Point I in FIGURE 18). Point I is located by measuring down from P along the line PN the distance found by multiplying the focal length times its enlargement factor by the tangent of one half of the tilt angle. For instance, if the depression angle (D) is 25°, the tilt angle is $90^{\circ}-25^{\circ}$, or 65°. One half the tilt angle is 32° 30'. The tangent of 32° 30' is .63707.

   The distance from P to I is 50 (6.35) (.63707) mm, or approximately 202.27mm.

   c. The position of Nadir is found along the Principal Line, by multiplying the focal length times its enlargement factor times the tangent of the tilt angle which was found in Step 7 a. Measure this distance down from the Principal Point (P) and mark its location. Label the Nadir "N."

8. Locate the "Scale Point."

Points in the photograph can be rectified directly to the scale of a map, by use of a scale point -- provided that the points lie at the

same elevation or the ground. This is very helpful in plotting the locations of points along the shores of a body of water.

The scale point is located by measuring down along the principal line from the true horizon. The distance measured depends on the scale of the map to which rectification is being made, the depression angle (D) and the flight altutude (H).

a. Find the "Scale Factor." The scale factor is the number of feet per inch at map scale. For instance, the RF map scale of a 7-1/2' USGS Quandrangle is 1/24,000 or 2,000 feet per inch.

b. The Scale Point formula is TS = H/Scale Factor (Cosine D). When working with enlargements, TS must be multiplied by the Enlargement Factor. Draw a line through S, parallel with the True Horizon.

FIGURE 19 illustrates the graphic procedures for projecting the locations of points onto a plane.

A. Select two points in the photograph which lie at the same elevation, and which can be seen on both the photograph and the map. Draw lines from T through these points, to the Scale Line. Construct vertical lines from the intersection points, parallel with the Principal Line. Draw lines from I through the images until they intersect with the vertical lines, which were drawn from the Scale Line.

B. Fit the tracing paper overlay over the map so that the last set of intersection points fall exactly over the map locations of the points which were selected.

From this point, any other point which can be seen in the photograph can be rectified directly to the map, provided that they are of the same elevation. If the points are not of the same elevation, they can frequently be relocated by inspection, so that an accurate overlay can be constructed.

If it is desirable to know the exact orientation of the oblique photograph, it is sometimes possible to draw a North arrow on the map, and "reverse rectify" it to the photograph. For accurate orientation, both ends of the North arrow must be at the same elevation on the map.

DRAWING PERSPECTIVE GRIDS ON OBLIQUE AERIAL PHOTOGRAPHS

Perspective grids are a series of lines which converge at the true horizon, that are crossed by a second set of parallel lines which are drawn at right angles to the principal line, TN. The second set of lines are progressively closer together as they approach the true horizon.

The pattern of lines is drawn in such a way that if, at the time that the picture was taken, the camera had been substituted for a projector, and the film for a slide with the pattern drawn on it, the lines, when projected onto the surface of the earth, would have formed a series of squares.

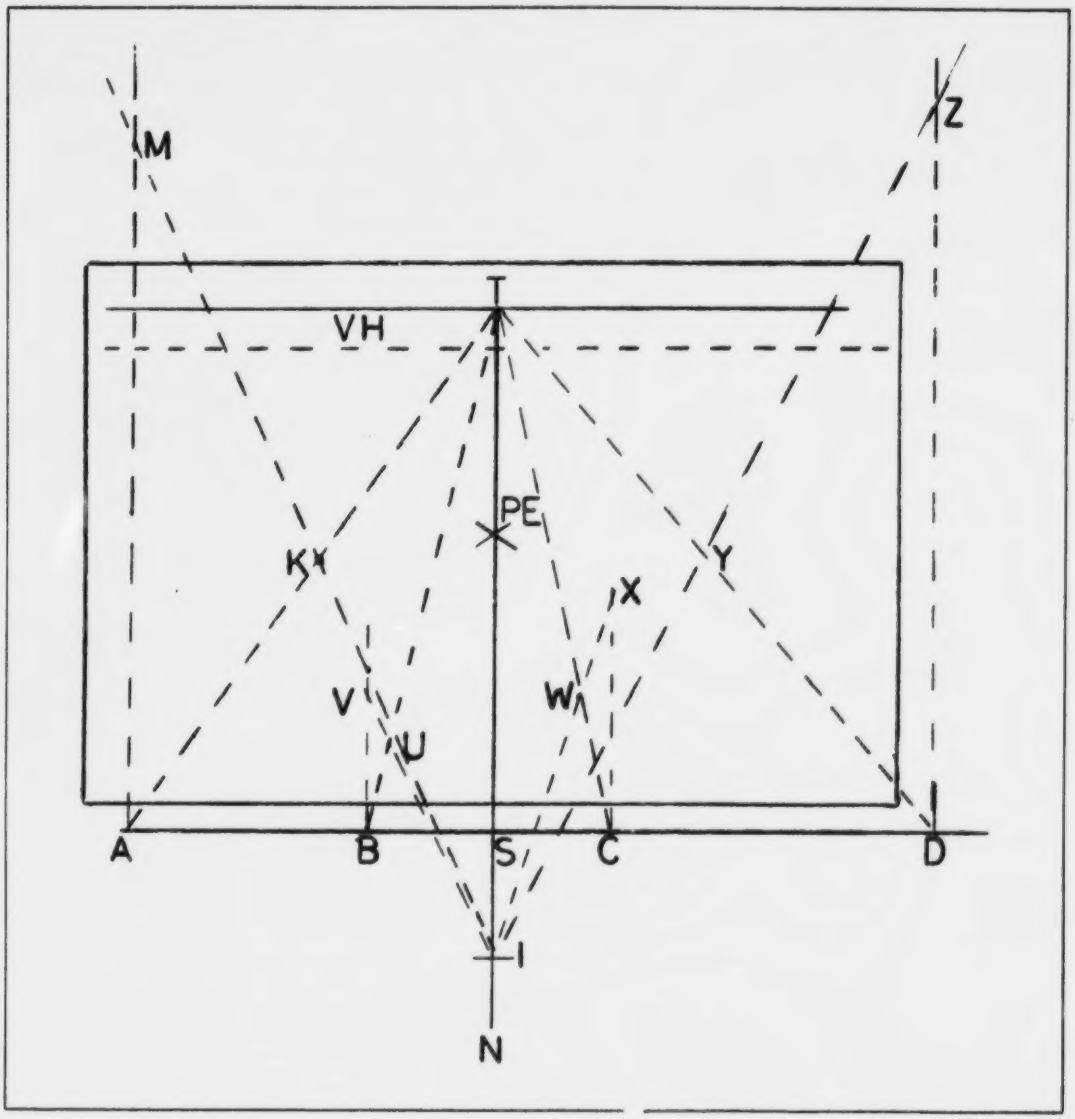


FIGURE 19 -- This diagram illustrates the graphic rectification steps which are required to plot the positions of features which can be seen in a low oblique aerial photograph directly to a map.

Step 1. Draw in the scale line, S (see Step 8, page 32).
Step 2. Draw rays from the true horizon point T to the scale line, through each point which is to be rectified (points K, U, W, and Y). These lines are labeled TA, TB, TC, and TD.
Step 3. Extend lines from A, B, C, and D, parallel with the principal line TN.
Step 4. Draw lines from I through each point whose position is to be rectified. The point where these lines cross the lines extended in Step 2 mark the rectified locations of the points. In the diagram point K is located at M, U at V, W at X, and Y at Z.

For direct map correlation, points M and Z would make suitable map correlation intersections.

The procedures outlined in this section describe how to construct perspective grids in which the ground area within each square is one acre.

Constructing perspective grids requires that the focal length of the camera, the altitude at which the aircraft was flying, and the depression angle of the camera when the photograph was taken all be known.

The following steps, for construction of perspective grids, extend from the basic graphic rectification procedures. It is recommended that the individual full-frame exposures be enlarged to 6 by 9 inch size when perspective grids are to be drawn to them. This will allow sufficient room for drawing lines directly to the individual photographs. Tape the enlarged photograph under a large sheet of tracing paper, near the center, so that the imagery on the photograph can be seen through it. Follow Steps 1 through 6 in Graphic Rectification, then proceed with the following steps in order:

1. Mark a tick mark on each side of T (on the true horizon line), the same distance as TI. Label the left tick mark G and the right tick mark H, as in FIGURE 20.

2. Draw a line at right angles through I across the principal line TN. This line is the isoscale line. Distances measured along this line are at the same scale as though the photograph was a vertical photograph taken with the same camera from the same altitude. When this is done, the basic scale calculation formula F/H (see FIGURE 1) can be used to calculate distances. In this formula, F is the focal length of the camera, and H is the flight altitude of the aircraft.

3. Using the basic scale relationship formula, calculate and measure off the positions of a series of tick marks along the isoscale line equal to 209 feet on the ground. For instance, if the photograph was taken with a 35mm camera with a 50mm lens from an altitude of 1,500 feet, the contact scale along the isoscale line would be approximately 1/9,000:

   $F = 2 \text{ inch} = 1/6 \text{ foot}; \quad H = 1{,}500 \text{ feet}: \quad F/H \quad \frac{1/6}{6(1{,}500)} = \frac{1}{9{,}000}$

   Since a 6 by 9 inch enlargement of a 35mm photograph has been enlarged 6.35 times, the enlarged scale is 1/1,430. Reduced to a scale of 1/1,430, 209 feet equals 1.77 inches, consequently, the tick marks should be placed 1.77 inches apart along the isoscale line, in both directions from I.

4. Draw a series of lines, one from each tick mark, which converge at T. The resulting fan-shaped array of lines should extend far enough to the sides so that the entire picture area of the photograph is included within the array of lines. These lines will become the Y axis margins of the final perspective grid squares.

5. Draw 45° diagonal lines G-I and H-I extending across the fan-shaped array of lines. These diagonal lines establish the X axes of each of the perspective grid squares.

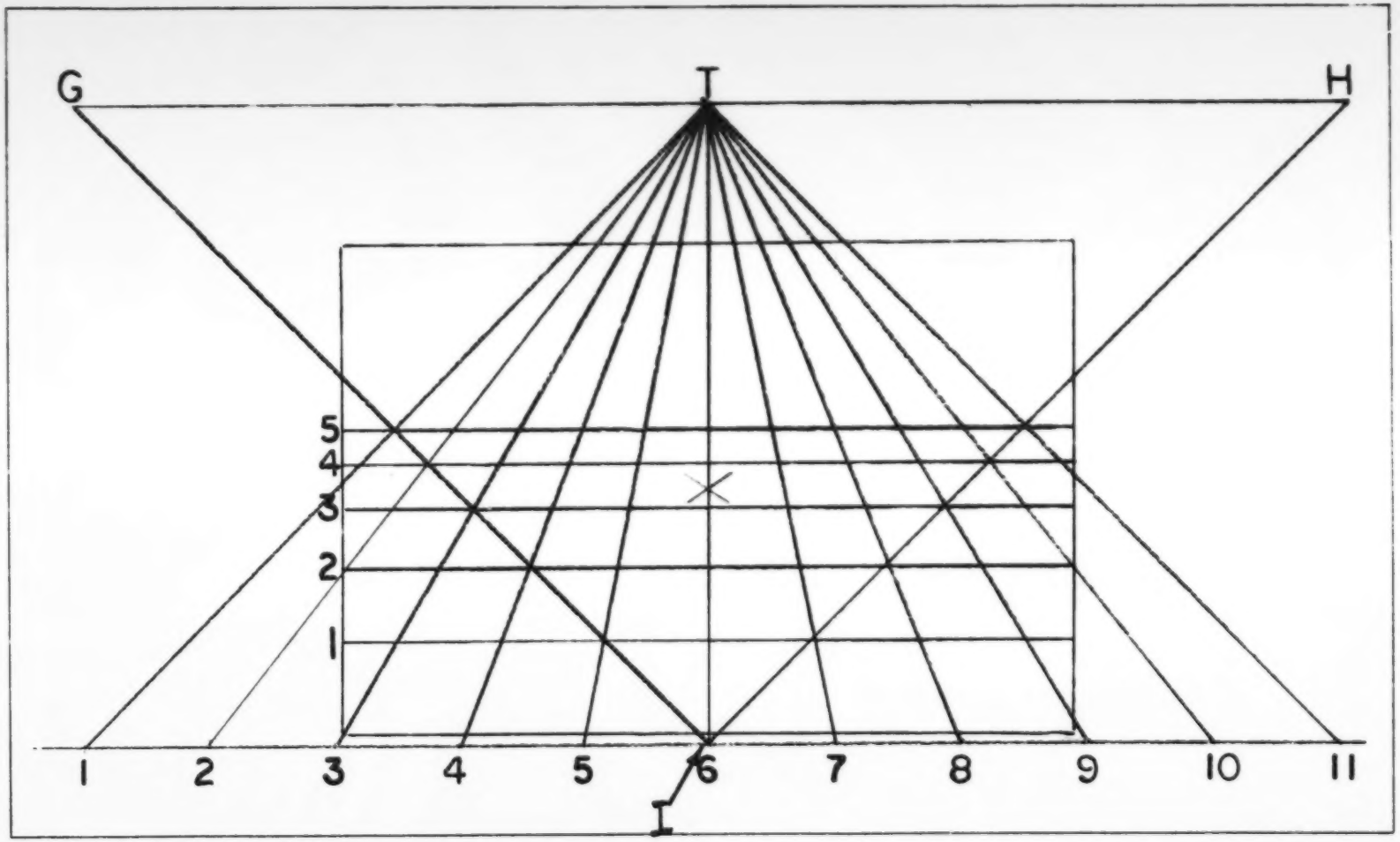


FIGURE 20 -- This diagram illustrates the appearance of a rectangular coordinate system extended over the projected plane of an oblique photograph, in the form of a perspective grid. As outlined in the text, the procedures recommended are those which will permit direct measurement of area in acres. A second valuable aspect of a rectangular grid system extended onto the plane of an oblique photograph is that it forms an excellent "point designation" grid system for reporting locations of features. In addition, of course, trigonometric and analytical geometric calculations are simplified.

6. With a straight edge, draw lines across the fan-shaped array of lines through each intercept of G-I and H-I with the Y axis lines drawn in Step 4. These parallel lines form the X axis lines of each individual perspective grid square.

   As can be seen, the spacing between each line, and the scale of the images, decreases to a very small scale as one progresses toward the top of the photograph from the principal point. This is particularly true in the case of high oblique aerial photographs.

   Because of the decrease in scale, little is to be gained in extending the X axis lines more than about one inch above the principal point, in the case of a 6 by 9 inch enlargement.

7. As a final step, draw a line around the format of the photograph, and starting from the right side of the print, number the Y axis (converging) array of lines from 1 to (n). Then, start in from the lower left, number the X axis lines from 1 toward the top of the perspective grid. Using this numbering system, trigonometrically, all calculations can be in the First Quandrant, and the locations of features in the grid can be reported following the basic military map reading system of "Read Right Up."

As an aid in use of perspective grids, it is suggested that a planimetric transfer grid be prepared, as shown in FIGURE 21. It is suggested that a standard sheet of graph paper which is divided into 1 inch square grids, and further subdivided into 1/10 inch squares be used for greater accuracy.

PERSPECTIVE GRID ANALYSES

FIGURES 22 and 23 are "working" illustrations. They are presented to illustrate the text of this section, and for direct use in projection analysis of 35mm oblique aerial photography. Using these techniques and exposure methods outlined in the previous sections, the geometry will be "built into" the final pictures. The spacing of the lines of these grids then permits direct measurements of acres.

For direct use of FIGURES 22 and 23, it is recommended that a standard photographic enlarger be used to project the photographs. Either 35mm black and white, or color transparencies can be used. For greater accuracy and convenience, it is suggested that slides be "unmounted" -- i.e., not fitted in paper, plastic, or metal 2 x 2 mounts as required for use in standard 35mm slide projectors.

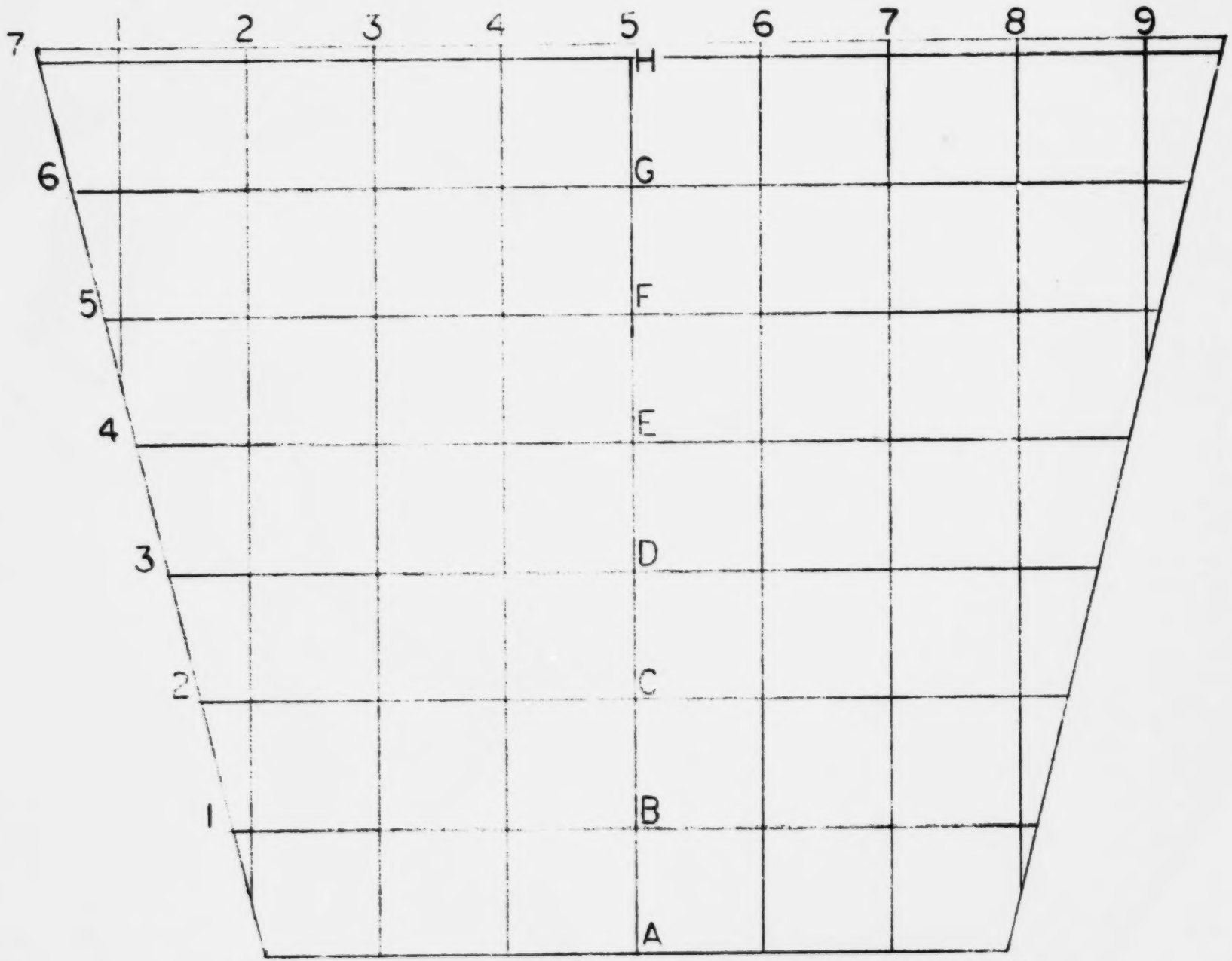
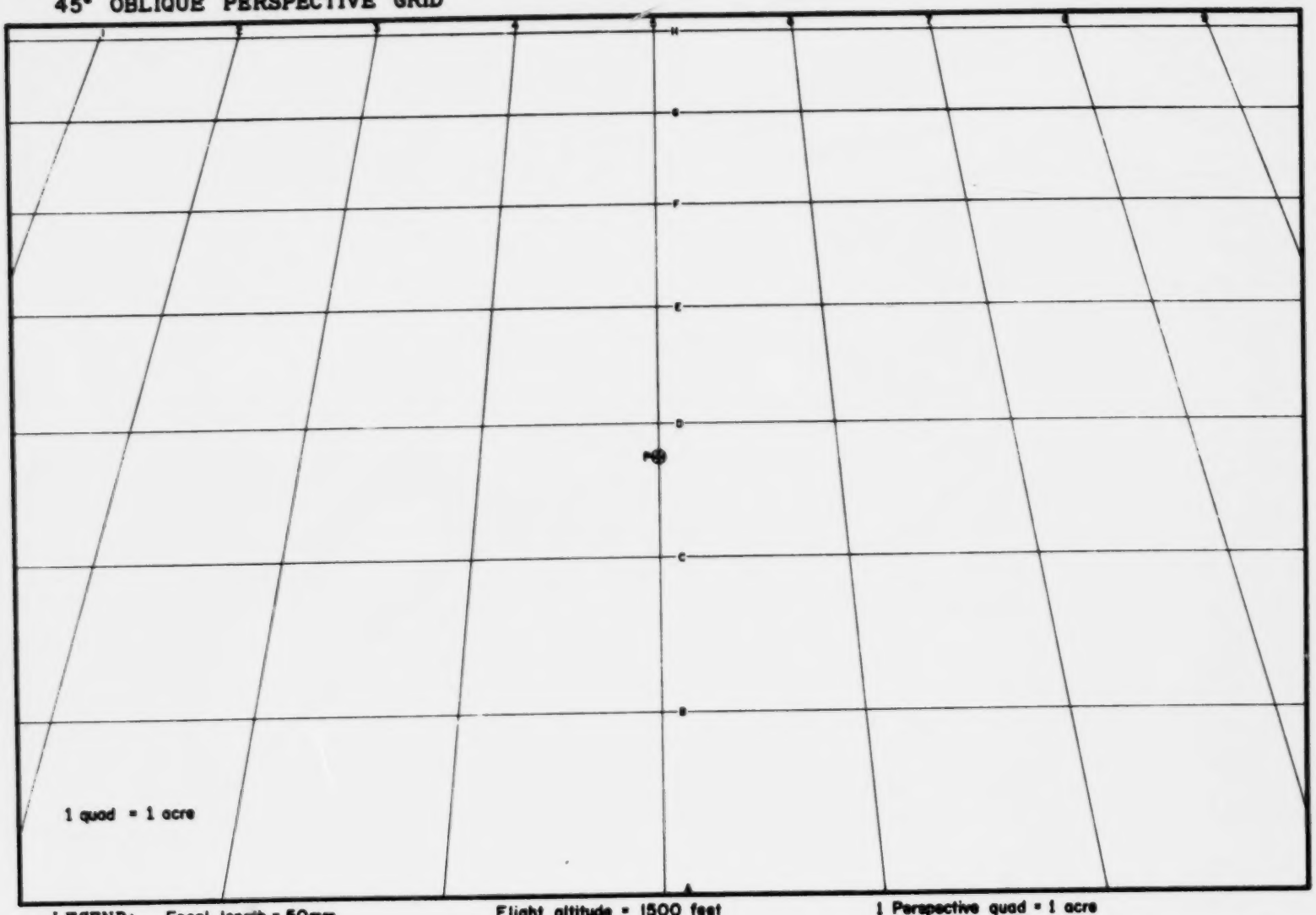


FIGURE 21 -- Transfer grid for 45° Low Oblique acre-square perspective grid.

FIGURE 22

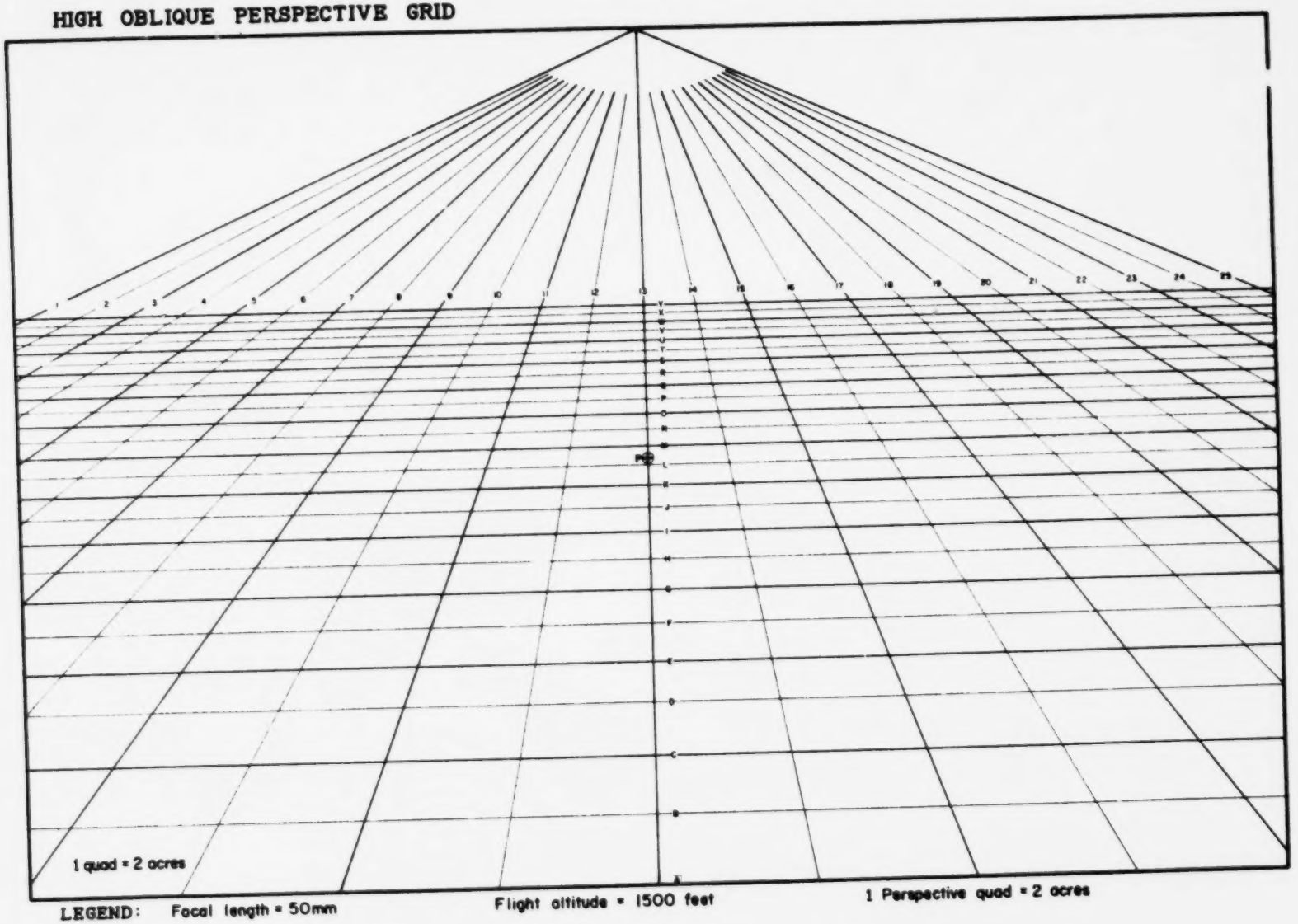
45° OBLIQUE PERSPECTIVE GRID



LEGEND: Focal length = 50mm Flight altitude = 1500 feet 1 Perspective quad = 1 acre

FIGURE 23

HIGH OBLIQUE PERSPECTIVE GRID



LEGEND: Focal length = 50mm Flight altitude = 1500 feet 1 Perspective quad = 2 acres

The perspective grids may also be drafted to 20" by 30" size, taped to a wall, and used as projection screen grids with a standard 35mm slide projector. If drafted onto transparent material, the grids may be used for rear-projection analysis.

Using these grids, two other techniques may be employed for direct measurement of area in acres. The first alternate procedure recommended is to photographically copy the grids, and print them as positive transparencies at the same scale as presented in this booklet. One may also trace the grids on sheets of Cronaflex drafting material or "frosted" acetate.

The transparent grids produced by either method are used with 6" x 9" full frame enlargements. The full frame enlargements are fitted under the grids, and direct measurement on acres made of the areas which are pictured. As mentioned in the preceding section, it is recommended that rectangular transfer grids be drafted on graph paper when this method is used.

Clear positive transparencies can also be used to print grid register lines directly onto normal photographic paper prints. When this method is used, direct analysis can be made on the enlarged prints.

OBLIQUE INTERPRETATION TECHNIQUES

Wise men, in discussing aerial photographic interpretation, have said that "the more knowledge you take to aerial photography, the more you can get out of your interpretation." This is certainly true, and since the purpose of this booklet is to outline procedural steps for taking and using aerial photography with 35mm cameras, no effort is made to help identify or interpret the specific images which are obtained.

Information in this section is limited to techniques which can be used for more effective study of 35mm oblique aerial photography.

STUDYING 35MM SLIDES WITH A MICROSCOPE

Lower-power (20X - 40X) microscopes can be used very effectively for direct study of 35mm slides. Accurate measurements can be made by use of a measuring reticule.

It is recommended that the slides be studied by transmitted light, by placing the microscope over an illuminating table (light table), or by use of a mirror system under the microscope, as illustrated in FIGURE 24.

Perspective depth indicators are quite prominent when a microscope is used to study slides. Much greater appreciation of perspective depth can be had any time that single photographs are viewed, if they are studied with just one eye, or, in the special case of direct study of slides, when they are studied with a microscope.

DIRECT STEREOGRAMS

In FIGURES 5 and 6, a stereo lens and a "direct" stereogram were illustrated. Direct stereograms are made by enlarging 35mm pictures, of

FIGURE 24 -- 35mm color and black and white transparencies and negatives may be very conveniently and effectively studied under a microscope. Place the microscope on a light table, position the slide in viewing position, and study the imagery by transmitted light. Eastman Kodak Kodachrome II can be studied under 40X magnification with no appreciable image degradation from graininess.

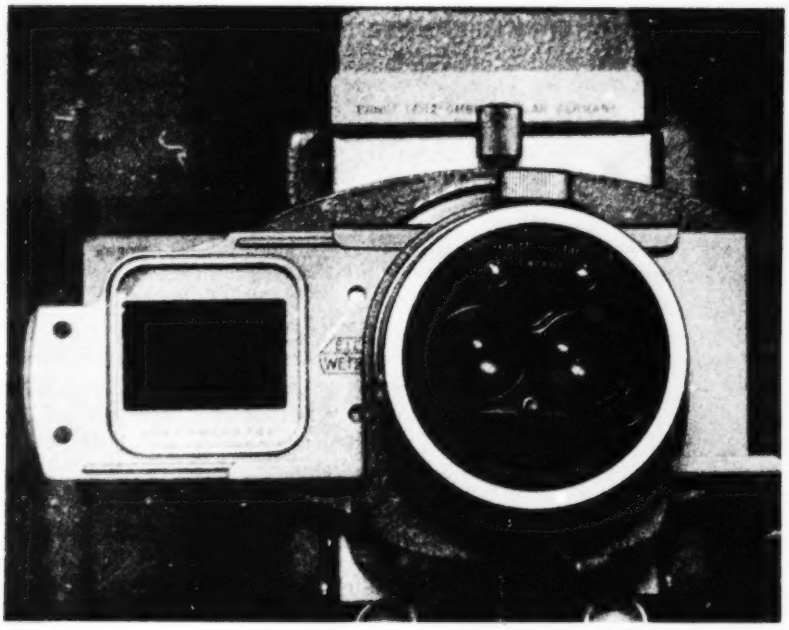
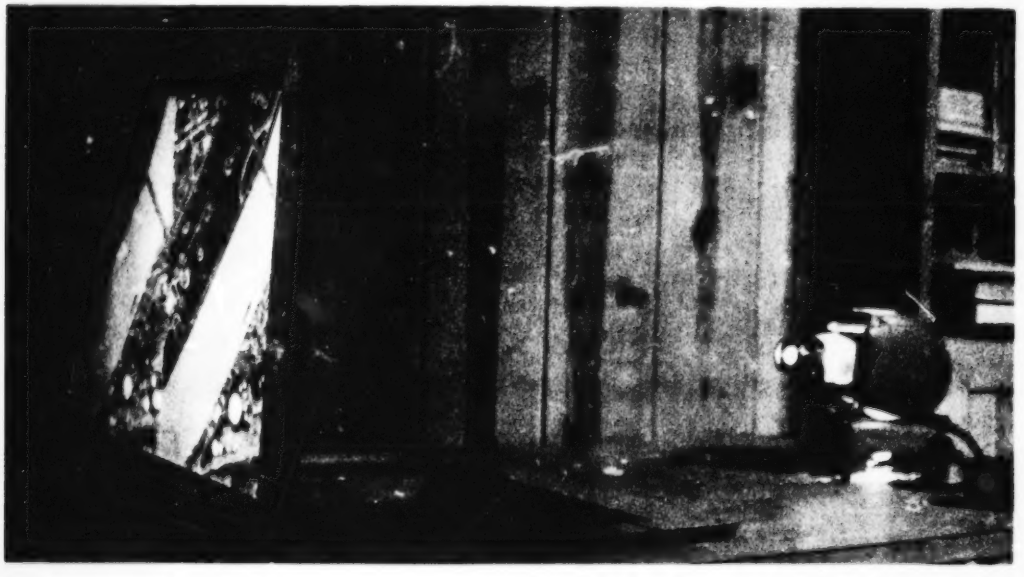


FIGURE 25 -- The Leitz Elmar stereo projection lens consists of two lenses separated by a "septum," or wall between them so that each lens can project its own set of imagery. Lens prisms behind each lens refract the projected imagery so that they overlap properly. Polorizing filters over each lens permit discrete recovery of each superimposed set, by use of polorizing glasses. When stereograms are mounted for projection, each half of the stereogrram must be very carefully positioned, so that the projected imagery will superimpose properly.

FIGURE 26 -- This illustration shows a Leitz Prado projector in use with a rear-projection screen. The transparency being projected is a stereogram, through a standard (single) 50mm lens, for comparative study of imagery.



the type taken with a Nikon or Leica stereo system, 3.35 times, so that the principal points of each picture are 2.375" (2-3/8") apart.

To be most effective, the pictures must be taken so that the slant range distance to the ground is not more than 1,800 feet. If the pictures are to be 45° obliques, then, H, the elevation above the ground should be not more than 1,250 feet.

PROJECTION INTERPRETATION

The prime advantage of projection interpretation is that several persons can study the photographs simultaneously. Since each person has at least a slightly different background of training and experience, each gains a different impression from the projected photographs. Collaborative interpretation and discussion concerning what is seen can be very beneficial.

Stereo slides, taken with a 35mm stereo camera, or precisely copied stereograms of the type and dimensions outlined in the preceding section can be projected with a stereo projection system, such as the Leitz Stereo Elmar. FIGURE 25 depicts this type of stereo projection lens, mounted in a Leitz Prado projector.

There are essentially two methods of projection -- reflection projection and "rear" projection. In reflection projection, the usual or conventional type, the projector is located in front of the screen and slides are projected onto the screne. It is recommended, however, that a beaded screen not be used, because the roughened surface breaks down small images. Instead, slides should be projected onto a smooth surface.

As in precise measurement, an enlarger can be very effectively used for projection interpretation.

REAR PROJECTION

Rear projection means that the projector is placed behind the screen, and the images are projected through the screen. Consequently, a translucent screen is used. A darkened room, such as is required for reflection projection, is not required. A sheet of 14 mil Type A Mylar® between two sheets of window glass mounted in a frame makes an ideal rear projection screen. FIGURE 26 illustrates a table-mounted screen of this type in use.

Rear projection offers several advantages. These include the fact that the room need not be darkened and that the interpreters can get close to the screen. This cannot be done in reflection projection because the interpreters would get between the projector and the screen.

Two fundamental points must be remembered. If reflection projection techniques are being used, the smooth side of the slides must be to the rear in the projector. If rear projection techniques are being used, the emulsion side of the slides must be toward the rear.

STEREOSCOPIC ANALYSIS TECHNIQUES
(See APPENDIX A "How to Use Folding Stereoscopes."

It is recommended that overlapping successively taken 35mm photographs be enlarged to 4" x 6" size, full frame, if they are to be studied stereoscopically.

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Most persons have the ability to see stereoscopically through a stereoscope, but may require practice.

FIGURE 27 is a vertical stereogram, presented to give the user of this booklet practice in seeing stereo with a standard folding stereoscope.

FIGURE 28 is a direct oblique stereogram which was taken with a Nikon stereo lens. It is also presented for stereo study practice.

Persons with normal eyesight see stereoscopically in nature. The images seen with the right eye are not quite the same as the images seen with the left eye. The differences in the images result primarily from parallax -- caused by the spacing (interocular distance) between the eyes.

The lens of the camera which took the successive overlapping aerial photographs substituted for both eyes of the observer. If the photographs were taken through the open right window of an aircraft flying toward the south, the camera lens substituted for the right eye of the observer when the first exposure was taken. When the second photograph was taken, the aircraft had traveled toward the left several hundred feet. When the second exposure was taken the lens of the camera served as the left eye of the observer. When the aircraft arrives in position for exposure of the third successive photograph, the lens of the camera again acts as the left eye of the observer, while photo number two, in a manner of speaking, is transformed to become the view observed with the right eye.

The flight distance between exposures has the same effect as would a tremendous increase in the distance between the observer's eyes. This effect is to increase the depth of stereoscopic acquity tremendously, and to exaggerate the stereoscopic appearance of features in the field of view.

Basically, images, once detected, are identified by shape, size, shadow, tone, texture pattern, location, and their relationship or incongruity with their surroundings.

The number of features which the interpreter detects, identifies, and realizes to be of significance for specific study purposes depends upon a unique combination of visual acquity, experience, interest and training.

Two methods of assembling and handling aerial photography for stereoscopic study are in common use. The same basic equipment, i.e., a folding stereoscope and colored (china marking) pencils to delineate features, are used in both methods. As previously discussed, image measurement, a requirement in most analysis, is more difficult in oblique photography.

The first method consists of individual stereoscopic analysis of successive prints. As an initial step, it is suggested that the approximate principal points of each consecutive photograph be located and marked. Next, the "transfer principal point" should be located in each photograph. The transfer principal point location is the point on successive overlapping photographs occuppied by the principal point of the preceding photograph. Location of these points will aid in orienting the photographs for stereo study.

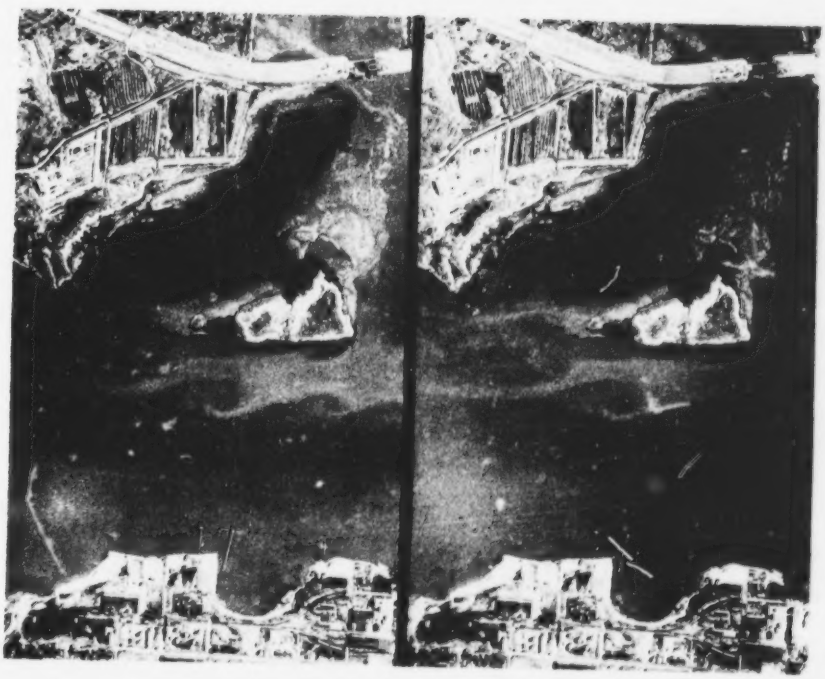


FIGURE 27 -- Practice Vertical Stereogram

Taken in January, 1961, showing a section of the Potomac River near Washington, D.C., current patterns induced by the changing state of the tide are vividly illustrated by the unusual appearance of the sediment suspended in the flowing water.

Viewed stereoscopically, these changes in speed and direction appear as changes in elevation of the surface of the water. More vividly illustrated when current velocity is higher, the changes in elevation are enhanced by thin patches of scattered ice floating on the river.

The arrow indicates the location of three industrial outfalls. The waste being discharged absorbs light having wavelengths longer than 640 Mμ.

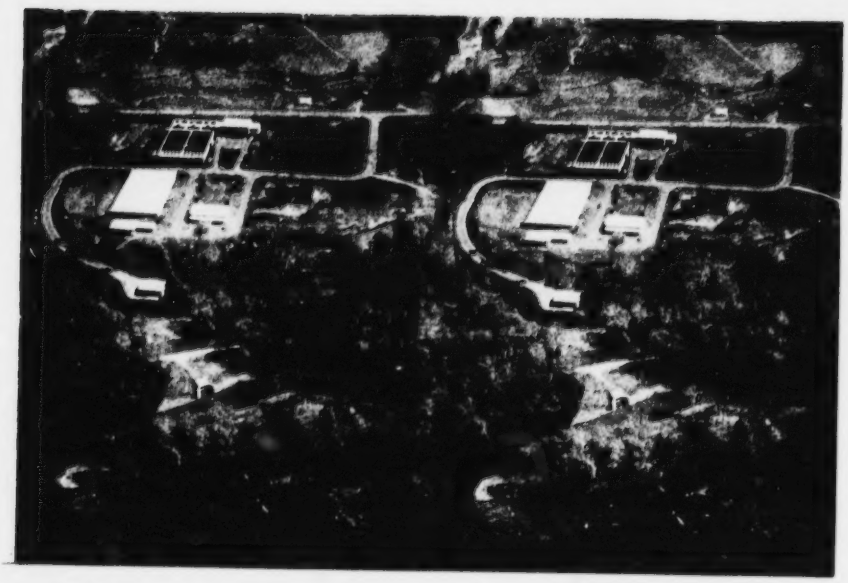


FIGURE 28 -- This oblique stereogram is presented for study purposes. It was made by enlarging a 35mm Nikon stereo photograph 3.35 times.

The photograph was taken with Eastman Kodacolor film, and is one of two prints which were made -- one in color and one in black and white -- from the same negative.

The water treatment plant which is pictured is located on the Potomac River north of Washington, D.C. The facilities are under jurisdiction of the Washington Suburban Sanitary Commission.

Align two successive overlapping photographs so that images of selected features are about 2-3/8 inches apart, as illustrated in FIGURE 27. The photographs must be positioned in correct order and should be positioned so that a line connecting the principal and transferred principal points of successive photographs is in line. If this is not done, only a small part -- if any -- of the area pictured in both photographs can be viewed stereoscopically.

Examine the area which can be viewed stereoscopically, and annotate those features identified as significant with china marking pencil. Standard procedures include drawing lines around or connecting significant features, and drawing standard symbols indicating features which have been identified. Standard military operations map symbols are used, for instance, in tactical and strategic military interpretation. Geological map and standard forestry symbols are used in geological and forestry photo interpretation. Normally, annotations are made directly on the right-hand photograph.

After the first two photographs have been studied, the photograph on the right side is turned upside down and shifted to the right. The photograph which comprised the left hand view is then shifted to the right, while the third photograph in the flight line is placed into position under the left lens of the stereoscope. This sequence of steps is repeated until all photos in the flight line have been analyzed.

Subsequently, the successive overlapping photographs may be layed out in strip fashion, and the inter-relationship of observed features studied and plotted on (or transferred to) a map.

The second method is the analysis of stereo-strip mosaics. Stereo-strip mosaics consist of a matched series of consecutive photographs, laid by matching the imagery of every other print in a series of overlapping prints preferably taken so that each photograph overlaps the next one 60%. In this way, the photographs which were taken between each of those which are fastened together can be studied in stereo by merely positioning them along the target center-line, and aligning them for study under a folding stereoscope.

FIGURE 29 illustrates an assembled stereo-strip oblique mosaic, with the alternate photos which lie in between off-set above and below the positions in which they must be fitted for stereo viewing.

Follow these steps for assembly of a stereo-strip mosaic:

1. Sort the successively taken overlapping photographs into two piles, even-numbered prints in one pile and odd-numbered prints in the other.

2. Lay out one set (the odd-numbered set was used to prepare FIGURE 29), and match the images so that a continuous picture is formed.

3. Trim the photos so that the numbers are preserved and cut the overlapping picture so that the two prints can be joined

with a square butt joint. Then fasten the prints together with Scotch "Magic" or similar high grade transparent tape. In the final assembly the print numbers should be visible, to aid in positioning of the photos which show the overlapping imagery. The pictured area is studied stereoscopically by correctly positioning the photographs in the other series between the joined alternate pairs, for study with a stereoscope.

In analysis, stream patterns and similar continuous patterns of images are annotated on the strip-mosaic. On completion of analysis, the interrelationships of observed and annotated features can be readily studied.

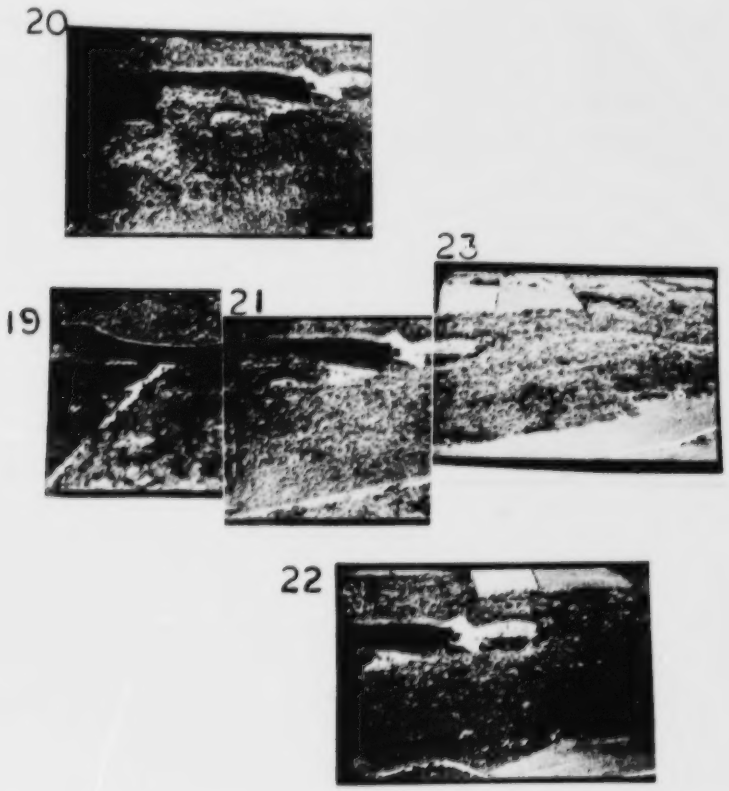


FIGURE 29

While the preparatory steps for the second method are more involved, the final analysis is frequently more thorough, and sometimes faster.

ILLUSTRATION TECHNIQUES

As has been stressed, a valuable application of 35mm aerial photography is for illustration of reports and oral presentations.

Two points should be stressed in collecting photography for illustration purposes.

First -- one of the cardinal advantages of 35mm photography is that ease of collection and lower cost permits coverage over a wider time range. Photography taken at intervals of several days, or on several successive days may help accentuate the appearance of natural features for illustrative purposes.

Second -- more persons in technical natural sciences fields are familiar with topographic maps than they are with aerial photography. Accordingly, it is recommended that, report space permitting, aerial photographic illustrations be oriented and keyed to sections of topographic maps.

35mm color slides are recognized as being very helpful in illustrating and stressing specific points in presentations made to large or small audiences. When aerial photography is being used, it is suggested that the speaker again keep in mind that more persons are familiar with maps than they are with aerial photography. A slide series covering features in an area is usually more effective when preceded by a slide showing a topographic map of the area being discussed.

It is suggested that "shaded" arrows, symbols and letters be used for annotation of key features in black and white photography being prepared for publication. Shaded symbols stand out better against a photo background. Suitable standard materials are available from art supply stores.

Oblique stereograms can be very helpful in report illustration.

The most convenient method of preparing oblique stereograms for inclusion in written reports is to enlarge pictures taken with a Nikon or Leitz stereo lens, as previously outlined.

Stereograms can also be made by cutting sections from successive overlapping photographs.

As an initial step, it is suggested that a transparent template, 2-3/8 inches by 3-1/8 inches be cut from clear plastic. Scribe lines centered from top to bottom and across the template, with a needle. It is suggested that these scribed lines be filled with red or yellow china marking pencil. Wipe off the excess material, then spray with clear spray.

Select two overlapping photographs, and locate the principal and transposed principal points. Connect these points with a light line, being careful not to scratch the emulsion of the photographs.

Place the stereogram template over the section of the right picture, centered on the most important feature which is to be illustrated. Insure that the scribed line crossing the template is parallel with the line connecting the principal and transposed principal points.

Cut this section out of the right photograph.

Next, carefully match the images which are pictured in the left picture, with the section which was cut from the right picture. Cut this section out, also.

Next, carefully glue the two sections, in correct order, to a sheet of heavy paper. Insure that the imagery is correctly aligned vertically. If alignment is correct, a line connecting the two views of the central image will be at right angles to the edge of the stereogram.

The recommended dimensions are such that the stereogram may be copied, full-frame, on 35mm slides, for stereo projection with a Leitz Elmar Stereo-Projection lens.

35MM AERIAL PHOTOGRAPHY IN COURT

Aerial photography which is to be used as evidence in a court of law in water supply and pollution control litigation will vary depending upon the nature of the violation and upon the laws of the State. However, the general types of pictures which may prove valuable include:

a. Pictures of the stream or other area in which contaminating wastes are being discharged.

b. Pictures which illustrate the damage resulting from the discharge of a contaminating substance, such as a resulting fish kill.

c. Pictures which prove the identity of the person or persons committing the violation.

Aerial photography offers special advantages as evidence in proving some types of water supply and pollution control laws, because pictures from an aerial vantage point can illustrate many conditions which cannot be seen from the ground. Since, fortunately, most conditions resulting from the discharge of wastes into flowing streams change very rapidly, aerial photographs can "freeze" conditions, providing a permanent record of what has occurred. Further, the ground or water areas which are affected may be very large and quite inaccessible. properly taken aerial photographs can be used to "transport the scene of the crime" into the court room.

Evidence photographs may be divided into two categories first, those which picture objects and/or areas, and which serve in place of a verbal description of the area second, those which are designed to prove a point bearing on the case, such as resulting damage.

Photography is usually considered admissible provided that it is an accurate representation of conditions which are in themselves admissible in court. The admissibility of a specific photograph is judged on the basis of the point which is to be proved, and how effectively it accomplishes this purpose. The presiding judge determines whether or not the photograph is admissible as evidence.

Photography which is to be offered in evidence is usually prepared in two forms: first, duplicate individual prints which are to be hand held by each of the jurors, the prosecuting attorney, the defense counsel, and the judge; second, a large display exhibit for use by the expert witness in explaining to the court in general the various parts of the subject matter to be discussed.

Individual prints which are to be distributed should be enlarged so that the points to be proven are clearly visible, yet not so much that the significant imagery is degraded by rendition of the clusters of silver grains which form the photographic imagery.

8 x 10 matte-dried glossy prints serve very well for this purpose.

If large single prints are to be used as part of the expert witnesses' support presentation, the degree of enlargement should be such that significant specific images have a diameter of at least one inch for each 25 feet of viewing distance. For instance, if a picture of an outfall is to be shown in court, and the jury is to be seated 50 feet from the point of presentation, the image of the outfall should be at least two inches in diameter. An enlargement 20 x 30 inches in size, neatly fastened to a plywood or masonite backing makes a good display.

Slide projectors can normally be used in a court of law. The rear-projection procedures which were covered as an analysis technique are well suited for this purpose, because lights, at most, need to be only moderately dimmed.

Color slides are also usually admissible, if color itself is significant to the case, or if it aids in explaining a point.

If the color itself is significant, the court will probably require that verification be made that the color is a fair and correct representation. Slight or inconsequential variations might affect the weight, but not the admissibility of the color picture.

IN SUMMARY

35mm aerial photography can serve many valuable functions where measurement, analysis to obtain data about inaccessible areas, preparation of illustrated reports, and presentations before audiences.

We hope that the techniques outlined in this Handbook will help you.

SELECTED REFERENCE LIST

BASIC AERIAL PHOTOGRAPHIC INTERPRETATION PHOTOGRAMMETRY,
and
AERIAL PHOTOGRAPHIC TECHNIQUES

1. "Manual of Photographic Interpretation" -- American Society of Photogrammetry. 44 Leesburg Pike, Falls Church, Virginia.
Entire manual recommended for general reference.

2. "Aerial Photographic Interpretation" -- D. R. Lueder, McGraw-Hill Publishing Company.
Entire manual recommended for general reference.

3. "Photogeology" -- Victor C. Miller, McGraw-Hill Publishing Co.
Entire manual recommended for general reference.

4. "Photogrammetry" -- F. H. Moffitt. International Text Book Company.
An excellent general reference for solution of photogrammetric problems.

5. "The Nikon Manual -- A Complete Handbook of 35mm Technique" -- George B. Wright. Universal Photo Books, 67 West 44th Street, New York 36, New York.

6. "Stereoscopic Photography" -- Arthur W. Judge, Chapman and Hall, Ltd., 37 Essex Street W. C. 2. London, England.

7. "Photographic Interpretation Handbook" -- NAVAER 10-35-610 (TM 30-245). U. S. Government Printing Office.
An excellent general publication.

8. "Photographic Measurements" -- Gomer T. McNeil. Pitman Publishing Company.
An excellent general reference manual.

In addition, it is recommended that users of this Handbook periodically review the list of publications produced by the Eastman Kodak Company. Their Data Books on "Infrared and Ultraviolet Photography," "Kodak Photographic Films and Plates for Scientific and Technical Use," "Kodak Wratten Filters -- for Scientific and Technical Use," and "Kodak Materials for Aerial Photography" are continually revised and kept up to date, and provide vital basic information.

HOW TO USE FOLDING STEREOSCOPES

Folding stereoscopes are simple instruments designed to help users see the imagery pictured on properly positioned overlapping aerial photographs in three dimensions. The basic parts of folding stereoscopes are:

FIGURE 1:

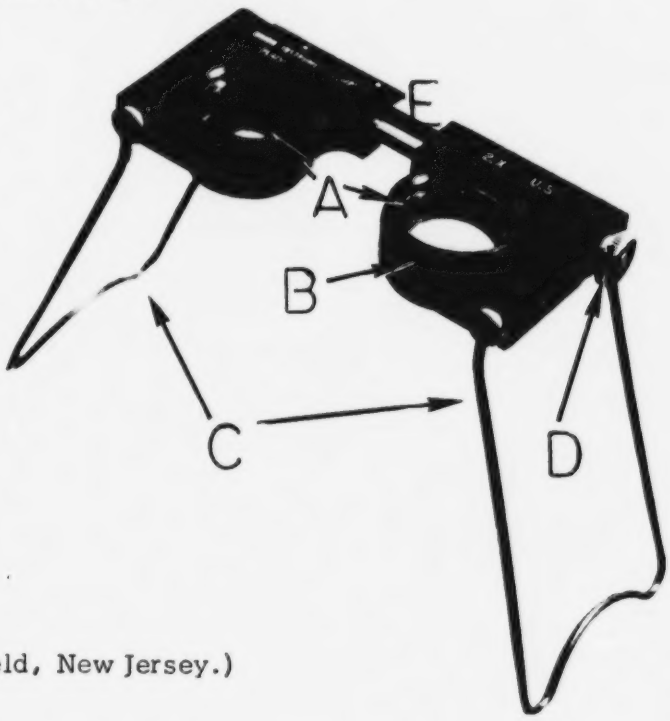
A - Lenses, usually 2X magnification.

B - Frame, to hold lenses correct distance apart.

C - Legs -- to hold lenses correct distance above photographs.

D - Vernier adjustment -- for precise adjustment of distance between lenses (found only on first quality instruments).

E - Lens Separation Scale -- to aid adjustment to fit users' eye-spacing.



(Courtesy Union Instrument Co., Plainfield, New Jersey.)

All persons (who have normal vision) see stereo naturally. Stereoscopes help users apply this ability to the study of overlapping sections of vertical or oblique aerial photographs.

The step-by-step instructions which follow outline standard methods for studying a vertical "stereo-pair":

1. Locate the Principal Point (PP) and the Transferred Principal Point (TPP)* of two successively taken overlapping aerial photographs. When correctly taken for aerial photographic interpretation, successive vertical photographs overlap 60%.

2. Align the photographs so that straight lines connecting the PP and TPP of the individual photographs are in line, as in FIGURE 2.

3. Adjust the photographs so that images of the same ground features are about 2-3/8 inches apart.

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*The Principal point of a photograph is the point which was directly behind the optical center of the lens at the time of exposure. The Transferred Principal Point is the point in the next photograph in which the image touched by the principal point of the preceding photograph is located.
FIGURE 2 illustrates the locations of the PP (A, B) and the TPP (a, b) in two typical vertical aerial photographs.

4. Adjust stereoscope so that distance between lenses is the same as it is between the users' eyes (about 65mm or 2.55 inches, average). Place the stereoscope over the photos so that images of the same feature are centered under each lens.

5. Look through both lenses at the same time -- eyes focussed at infinity as through looking at a distant object. Some users see stereo the first time they try. Others need more practice. Most first-time stereoscope users initially "see" two distinct images -- which gradually fuse together creating the impression of a third image in between the two pictures "seen" in the first impression. The third image is usually in stereo. With just a little more practice, the two images fuse into stereo effortlessly, yielding the satisfaction of studying the terrain as though it were a precisely-detailed, minutely-perfect model.

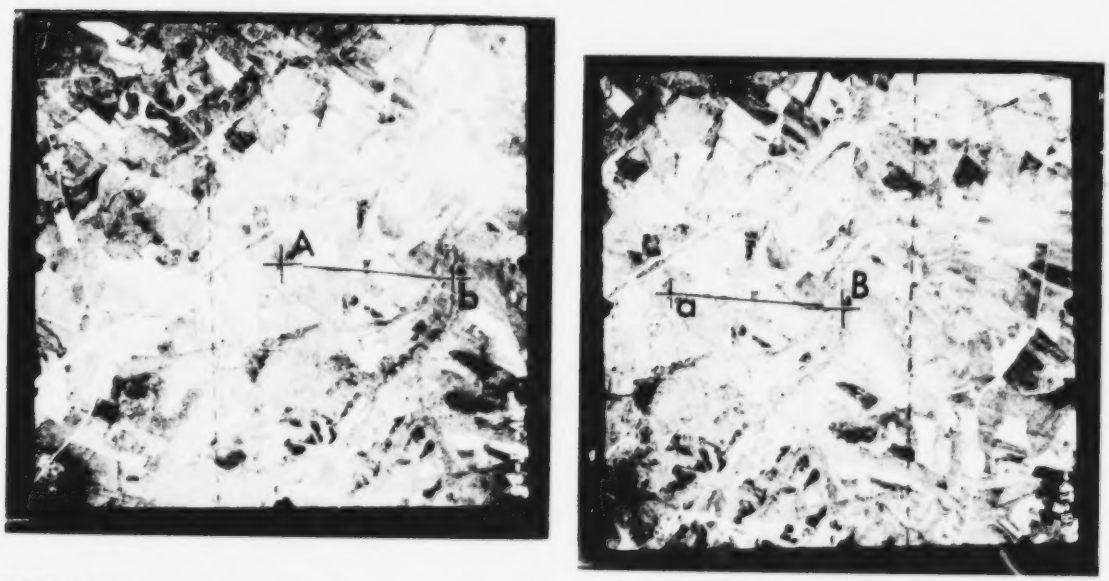

FIGURE 2 -- "A" and "B" are the locations of the Principal Points (PP) of the two aerial photographs. "a" and "b" are the locations of the Transferred Principal Points (TPP). Note that point "a" covers the same point on the ground as does point "A", and "b" the same point as point "B". The small index marks on the edges of the photographs are fiducial marks -- to aid in locations of the Principal Points. Note that straight lines connecting opposite fiducial marks cross at the marked Principal Points.

The full size of these aerial photographs is 9" x 9". They were taken from an altitude of 13,750 feet (average) over the ground, using an aerial camera fitted with a lens having a focal length of 8-1/4". Photograph NV-4T-89 was taken first. The plane flew from A to b (same ground distance a to B). The whole area within the dashed lines can be studied in stereo. This illustration may be used as a "stereogram" to verify the extent of stereo coverage.

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POCKET STEREOSCOPES

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Our recently developed magnifying pocket stereoscopes are equipped with achromatic doublet elements of the highest quality, fully corrected for flatness of field, free of astigmatism and chromatic aberration.

These stereoscopes are precision built of black anodized aluminum and stainless steel. The hardened steel legs rigidly lock in proper position.

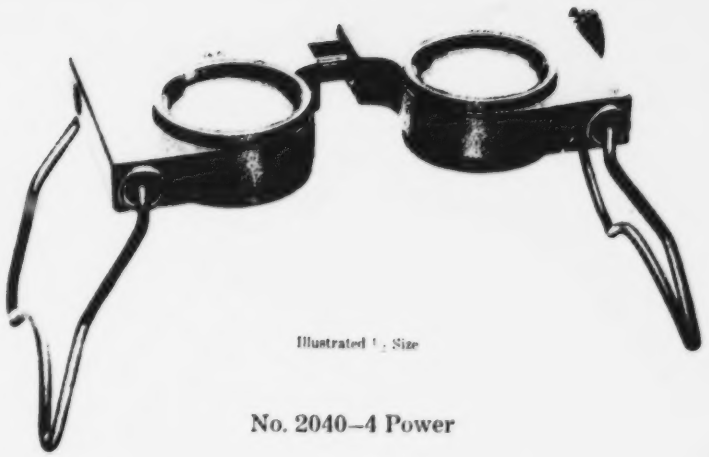
The two-power instrument resolves no less than 22 lines in a flat viewing field of 3½ inches in diameter.

The four-power stereoscope resolves no less than 25 lines in a flat viewing field of 1¾ inches diameter. The lenses are mounted in threaded cells for critical individual focusing.

Interpupilary adjustment is made by a positive screw mechanism with millimeter scale from 55 to 72 mm.

Furnished in leather carrying case.

No. 2020–2 Power
No. 2040–4 Power



Illustrated ½ Size

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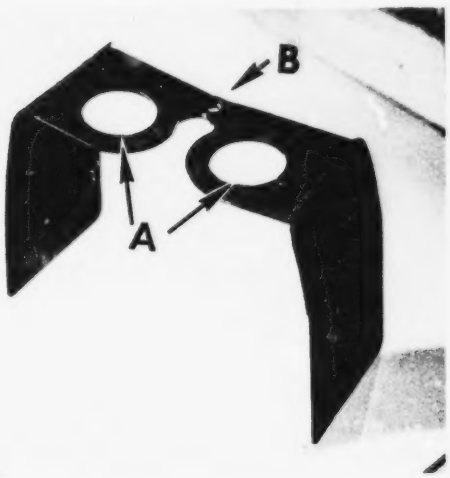
THE SIMPLEX STEREOSCOPE

SIMPLEX STEREOSCOPES ARE SIMPLE INSTRUMENTS DESIGNED TO INTRODUCE SCIENTISTS TO THE STUDY OF PHOTOGRAPHIC IMAGERY STEREOSCOPICALLY



A -- precision moulded 2-power lenses by AMERICAN OPTICAL COMPANY.
B -- Lens separation pivot.

SIMPLEX STEREOSCOPES are specially constructed of a heavy type of special cardboard, fitted with precision-moulded plastic lenses by the AMERICAN OPTICAL COMPANY. Two-Power wide-field lenses help users see image details clearly. SIMPLEX STEREOSCOPES are ideal for training, demonstration, and short instructional courses.

HOW TO USE SIMPLEX STEREOSCOPES

All persons who have normal vision see stereo naturally. Stereoscopes merely help users apply their natural ability to the study of properly positioned overlapping vertical and oblique aerial photography.

The Step-by-Step methods which follow outline a standard method for study of a vertical "stereo pair."

1. Locate the Principal Points (PP) of each photograph in the stereo pair. The PP are at or near the center of each photograph. They are the points which were directly behind the center of the lens system at the time that the pictures were taken. PP are located by drawing straight lines connecting opposite "fiducial" marks on the edges of the photographs.

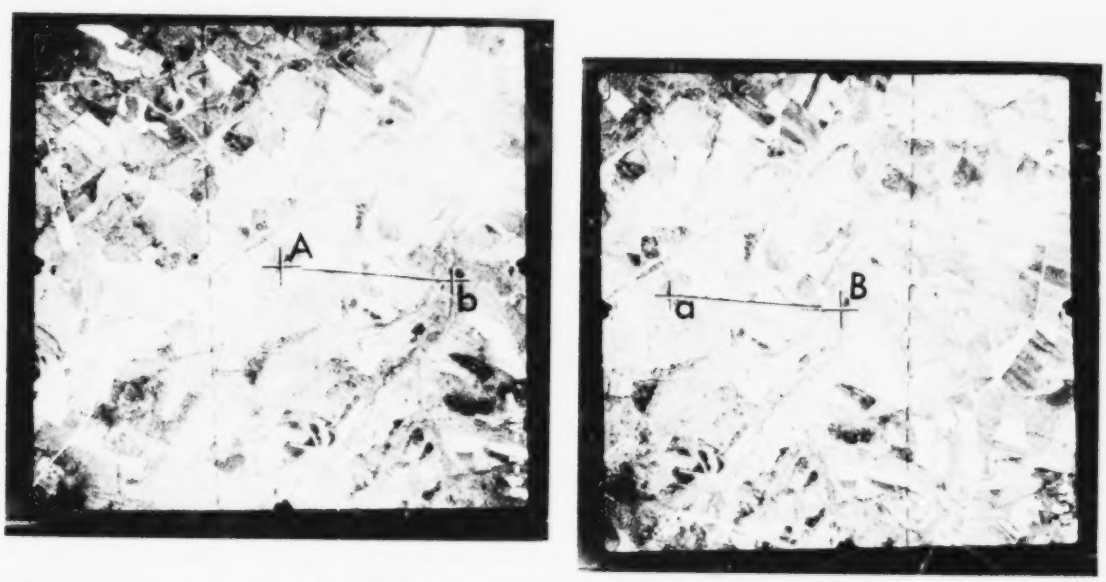
2. Locate the Transferred Principal Points (TPP) on each photograph. These are the image points where the PP of the other photo in the stereo pair are located.

(OVER)

3. Connect the PP and the TPP of each photograph with a straight line. Insuring that the photographs fall in consecutive order, position the photographs so that the lines connecting the TPP and PP of each photograph are aligned, and so that images of the same ground features are about 2-3/8 inches apart. (See Figure 2)

4. Adjust the SIMPLEX STEREOSCOPE by a simple scissors movement so that the distance between the lenses is the same as the distance between the users eyes. Place the SIMPLEX over the Stereo-pair so that images of the same ground features are centered under each lens.

5. Look through both lenses at the same time, eyes focused at infinity as though looking at a distant object. Some users see stereo the first time they try. Others need more practice. Most first-time stereoscope users initially "see" two distinct images -- which gradually fuse together creating the impression of a third image between the two pictures "seen" in the first impression. The third image is usually in stereo. With just a little more practice, the two images fuse into stereo effortlessly, yielding the satisfaction of studying the terrain as though it were a precisely-detailed, minutely-perfect model.



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